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TO

PROFESSOR R. E. GRANT, M.D.,

F.R.S., F.R.S.E., F.L.S., F.G.S., F.Z.S., ETC.,
PROFESSOR OF COMPARATIVE ANATOMY AND ZOOLOGY IN UNIVERSITY COLLEGE, LONDON,
ETC., ETC.,

This Volume is Dedicated,

WITH THE MOST SINCERE RESPECT
FOR HIS PROFOUND KNOWLEDGE OF NATURAL HISTORY IN GENERAL,
AND ESPECIALLY FOR THE LUCID AND ABLE MANNER
IN WHICH HE LED THE WAY IN THE SAME FIELD OF INVESTIGATION AS THAT
OF THE PRESENT WORK,
AND WITH MUCH GRATITUDE FOR THE KIND ADVICE
AND LIBERAL ASSISTANCE THE AUTHOR HAS RECEIVED FROM HIM
DURING THE COURSE OF ITS PREPARATION.

PREFACE.

In treating a subject so new, and to a great extent so obscure, as the 'History of the Spongiadæ,' it may reasonably be deemed necessary that the author should explain to his readers the origin and object of the work which he presents to them.

The highly interesting and valuable researches of Professor Grant in the unexplored field of their anatomy and physiology published in the 'Wernerian Memoirs,' and in the 'Edinburgh New Philosophical Journal,' and the labours of Dr. Johnston, in collecting and identifying the species described by numerous authors, ably concluded and published in his 'History of British Sponges,' in 1842, naturally created an interest in these singular creatures that had never before been excited to so great an extent, and which led naturalists to believe that a new and pleasing field of investigation lay before them.

Impressed with these ideas, I made some desultory

observations on their structure, the publication of which led to frequent communications with my late amiable and talented friend, Dr. Johnston, who strongly urged me to commence a more extended systematic investigation of the structural peculiarities of exotic as well as of native species. Thus stimulated, I commenced my investigation of their anatomy, and speedily found in their structure so much that was curious and beautiful, so many admirable mechanical and physiological contrivances that I soon became deeply interested in the subject.

The British sponges alone have afforded me a very extensive series of new and beautiful forms of organization, and as my knowledge of the number of the species and the peculiarities of their structure became extended, I quickly became aware that the list of our native species contained representatives of nearly every known genus of these animals, and that such an extension of my investigation as that published in the present volume became absolutely necessary to complete the terminology not only of the British species already described, but those also which the future researches of naturalists may make known to us.

In the pursuit of this object I have done my best to rescue the hidden wonders and beauties of these extraordinary creatures from comparative oblivion, and their examination and investigation have been for more than a quarter of a century a continuous source of fresh pleasures and surprises to me; but, although in the course of these researches I have examined a very large number of exotic as well as of native species, I can assure my readers that I have by no means exhausted the subject, and that a rich field of pleasure still remains to be explored by future

naturalists who may be induced to pursue similar investigations, and they will, I trust, find their labour facilitated by the endeavours I have made to systematise the species, and to construct a language of description by which their parts may be known and described by future students of their history. The necessity for this extension of my subject beyond the limits of the British species, becomes the more apparent when we consider that in the larger portion of living creatures our knowledge of them may be greatly facilitated by accurate figures of their external forms and their colour, but we have this assistance to a very slight extent with the Spongiadæ. No two specimens of a species agreeing precisely in form with each other, and the discrepancies in shape arising from differences in age, degree in development, and the varied influences of locality, are such as to perfectly bewilder the student who depends on external form as a means of recognition, and to complete his confusion the variations of colour to which many species are subject is almost as great in proportion as that of external form. To these difficulties, perhaps, we may in a great measure attribute the neglect with which this branch of marine natural history has been treated, and the slow progress that has been made in acquiring a knowledge of them, even by the most enlightened and philosophical of the naturalists of the past and present centuries. Their nature is also such as to present scarcely any attractive feature to the curious student in zoology. No animal motion, no functional demonstration is visible to the eye of the casual observer to attract his attention from the active and more beautiful tribes of marine animals amidst which they are found, and it is only when we sit down studiously to examine their anatomical structure by the aid of a good microscope that we become aware of the ex-

ceeding variety and beauty of their structure, and are thence induced to investigate the living actions of organs so numerous, varied, and beautiful as those displayed to us by a careful examination of their structure. With these difficulties surrounding my earliest attempts at the recognition of species, and with a rapidly increasing knowledge of the variety and beauty of the tissues which presented themselves, as I proceeded with my investigation I felt the necessity of abandoning external form and colour as descriptive characters, and determined patiently to work out a series of descriptive characters based on the peculiarities of anatomical structure, and thus it is that in accordance with the necessities of this preliminary labour, the introduction to the history of the British species has become dilated into an attempt at a general history of the anatomy and physiology of the whole of the Spongiadæ.

The accomplishment of this task would have been comparatively hopeless without the very kind and liberal assistance of numerous friends

To the late Dr. Ayres, of the Mauritius, I am indebted for a very interesting collection of sponges from that locality; and to Mr. Joshua Alder, of Newcastle-upon-Tyne, for frequent contributions of British species. The late Professor Bailey, of New York, kindly supplied me with specimens of Spongilla from North America. To Mr. H. W. Bates I am indebted for my knowledge of some of the most interesting species of the Spongillidæ of the river Amazon; and Mr. J. Spence Bate I have to thank for the loan of many interesting species of British sponges. To my late friend, Mr. G. Barlee, I am deeply indebted for repeated collections of British species of sponges from

the Orkneys and Shetlands, containing the types of some of the most interesting of our native species. To Mrs. Brett, of Tenby, I have in like manner to return my best thanks for repeated contributions of new and interesting species; and I am also greatly indebted to my friend Mr. Bean, of Scarborough, who has, with his accustomed kindness and liberality, contributed numerous specimens to my cabinet, and has placed the whole of his rich collection of sponges at my service for examination and description. I am also greatly obliged to the late Mrs. Dr. Buckland for many interesting specimens collected by her at Sark and Guernsey. My late friends, Mr. Robert Brown and Mr. Lucas Barrett, have also favoured me with valuable contributions of specimens. I have also to thank Dr. Battersby, of Torquay, for similar kind assistance. To Mr. H. J. Carter, late of Bombay, I am greatly indebted for an abundant supply of the species of Spongilla so ably described by him in the 'Journal of the Bombay Branch of the Royal Asiatic Society,' No. XII, 1849, and for an interesting collection of sponges from the neighbourhood of Aden. To my friend Mr. George Clifton, late of Freemantle, Western Australia, I am especially grateful, for the numerous and large collection of the sponges of that locality with which he has favoured me, through which, from their fine state of preservation, I have obtained many beautiful varieties of organization that I was before unacquainted with. To Mrs. Collings, the lady of the Seigneur of Sark, I have also to return my best thanks for much kind information and assistance regarding the marine productions of the Channel Islands. Mr. Hugh Cuming has also my best thanks for having assisted me in obtaining many interesting specimens, and especially for the kind and liberal use he has allowed me of his beautiful specimen of *Euplectella aspergillum*,

Owen. Professor Dickie, of Aberdeen, has also kindly allowed me the use of his valuable collection of northern specimens of sponges. To my friend Mr. Dunsterville, of Algoa Bay, I am indebted for a fine collection of the sponges of that locality; and to Mr. H. Deane, of Clapham, for rare specimens of Spongilla from India. I have to thank Professor Milne Edwards, of Paris, for much kind assistance during my visits to the museum of the Jardin des Plantes; and also my friend Dr. A. Farre, for the liberal use he has allowed me of his fine specimens of *Farrea occa* and *Euplectella cucumer*, Owen; nor must I forget my late friend, Professor Edward Forbes, who kindly supplied me with several rare species of British sponges. To my friend Professor Grant I am, indeed, deeply indebted, especially for the use of the type specimens of British species described by the late Colonel Montagu, and those presented to him by the late Dr. Fleming, and also of specimens of those species which he had himself described, by the means of which I have been enabled to recognise many species described by the authors mentioned above, and also by Dr. Johnston, the identity of which must otherwise have remained in much doubt and uncertainty. To my late friend, Mrs. Griffiths, of Torquay, and to the Rev. Walter Gregor, of Aberdeen, I am equally indebted for numerous interesting species collected in the neighbourhood of Torbay, and Macduff in Banffshire. My best thanks are also due to Dr. Dawson, of McGill's College, Montreal, for several contributions of North American marine sponges, and for specimens also of Spongilla from the river St. Lawrence. Dr. Asa Gray, of Boston, and Dr. J. Leidey, of Philadelphia, United States, I have to thank for specimens of North American Spongillas, and Mr. J. K. Lord, for the loan of similar specimens from Vancouver's Island.

To my friend, Dr. Leared, I am much indebted for some valuable and highly interesting specimens of the sponges of commerce, in the condition in which they came from the sea, and for a collection of marine sponges from the shores of Iceland. To Dr. Lister, of Madeira, and to my friend, Mr. J. J. Lister, of London, my thanks are also due for donations of marine sponges. Professor Harvey, of Trinity College, Dublin, has also favoured me with some interesting specimens of sponges from Australia. To my friend Mr. James Hilton, I am indebted for several new and interesting forms of sponge spicula from the Indian Ocean, and to Mr. George Hyndman, of Belfast, for many interesting species from Belfast Lough, and other Irish localities. My late friend, Commander Ince, R.N., favoured me with a collection of sponges from the Chinese seas and other localities. To Mr. J. Yate Johnson, of Madeira, I am much indebted for sponges containing several new and very interesting forms of spicula and organization, which are figured in this work, and also to my late friend Dr. Johnston, of Berwick-on-Tweed, for numerous acts of kindness, and for many interesting specimens of West Indian sponges. My late friend Mr. Thomas Ingall, contributed largely to my knowledge of new forms of spicula and other organs of the Spongiadæ by numerous donations of interesting species, and by placing the whole of his extensive collection of sponges and of microscopic objects illustrative of their structure at my service for examination. My late friend, Mr. Rupert Kirk, of Sydney, kindly supplied me with a large collection of sponges from Wollongong, near Sydney, and his son, Mr. Richard Kirk, a similar collection from Port Fairey. My best thanks are also due to Mr. Robert McAndrew, for numerous specimens of British species, and for several highly interesting and valuable sponges from the Coast of Norway, the structures

from which are figured in this volume. My friend, the Rev. A. M. Norman, of Sedgefield, near Ferrybridge, Durham, has largely contributed to the list of new British species, which will be published in the second volume of this work, by having with the greatest liberality and kindness, continually placed the results of his numerous dredging excursions at my disposal for examination.

My indefatigable friend, Mr. C. W. Peach, of Wick, N.B., has also continually and frequently favoured me with numerous northern species; and to my friend, Mr. Robert Patterson, of Belfast; my late friend Mr. William Thompson of the same locality, and to Mr. William Thompson of Weymouth, I am similarly indebted. My late friend Mr. S. P. Pratt, favoured me with a collection of East Indian sponges, from which several highly interesting types of beautiful forms of organization have been figured in this volume. My friend Captain Thomas, R.N., of the Hydrographical Survey, has also assisted me greatly with numerous interesting specimens acquired in the course of his professional avocations. To my late friends, Professor John Quekett and Mr. J. H. Stewart, of the Royal College of Surgeons, I am under great obligations for numerous kind acts and many valuable specimens of organization, and I am also much indebted to my friend Mr. Charles Tyler, for much valuable assistance in the examination of exotic sponges in search of new forms of organization. In addition to the above I must also tender my thanks to Professor Ansted, Professor King, of Galway, Mr. N. H. Mason, Mr. J. Gwyn Jeffreys, Mr. Howes, of Newcastle, Mr. Tumanowicz, Mr. Vickers, of Dublin, and Mr. C. M. Topping, for their kind donations of specimens. To my friend, Mr. William Ferguson, of Burton-on-Trent, I

am also indebted for much kind classical assistance in the preparation of the nomenclature.

And lastly, I must not omit expressing my acknowledgements to Mr. W. Lens Aldous, for the exceedingly accurate and beautiful delineations, by the aid of the microscope and camera-lucida, of the delicate and frequently complex tissues which illustrate this work.

I fear that, in the performance of this agreeable duty of thanks to the numerous friends who have so generously assisted me, I may have inadvertently omitted the mention of some who have favoured me with specimens or other assistance, but to those I have named, and to all who have contributed either information or specimens, I beg to present my most sincere thanks.

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ANATOMY AND PHYSIOLOGY OF THE SPONGIADÆ.

ON

THE ANATOMY AND PHYSIOLOGY

OF THE

SPONGIADÆ.

I. ORGANOGRAPHY.

Naturalists are deeply indebted to Dr. Johnston for having, with great labour and patient research, collected together all the widely scattered information that existed on the subject of the Spongiadæ, and for having, with so much sound judgment, reduced the comparative chaos of facts and opinions regarding them to such a condition of order as to greatly facilitate the labours of succeeding students. He has displayed in the three introductory chapters to his 'History of British Sponges' such an extent of reading and research, from the earliest writers on natural history to the latest authorities on those subjects, such an admirable and lucid condensation of the information he has thus obtained, as to render them one of the most valuable and satisfactory treatises on this obscure branch of natural history that has hitherto been written. It would, therefore, be a work of supererogation on my part to endeavour to dilate on that portion of our subject, and I am satisfied that I cannot do better than to recommend to students in this branch of natural history the careful perusal of his intro-

duction to the study of the Spongiadæ, as an excellent preparation for the investigation of the British species.

From the researches of Dr. Johnston, detailed in Chapter III, "The Discovery of British Species," it appears that the first British sponge recorded was by Mathias de l'Obel, in 1616. Ellis, in his 'History of British Corallines,' 1755, described two species, and in his 'Zoophytes,' 1786, edited by Solander, the number is increased to seven; other species were described by Professor Jameson and Mr. James Sowerby; and, in 1809 fifteen indigenous species were known. In 1812 Colonel Montagu extended the number to thirty-nine, and in 1852 Dr. Johnston further increased the number to fifty-six. But from these we must deduct eleven, which are only repetitions under new names, or, otherwise, no species; reducing the correct number of species known to forty-five.

In endeavouring to verify these species, I found, apparently, insuperable difficulties arising from the exceedingly unsatisfactory condition of the descriptive language employed by preceding authors, while, at the same time, I was struck by the abundance of excellent characters that were to be derived from the structural peculiarities of the animals. Up to the present time the Spongiadæ have been classified either by their external form or in accordance with their chemical constituents. In the second edition of Lamarck's 'Anim. s. Vert.,' 138 species are included in the genus *Spongia*, without the slightest reference to their internal structure; and they are divided into seven groups by external form only, the same characters serving also, in a great degree, to discriminate the species.

Fleming, Grant, Johnston, and other modern naturalists, have made their principal divisions depend on their chemical constituents, and have therefore constructed three great divisions as genera :—*Spongia*, composed of keratose fibres unmixed, as it was supposed, with earthy matter; *Halichondria*, formed principally of siliceous spicula; and *Grantia*, having the skeleton composed of calcareous spicula. Included in the second of these divisions are the genera *Tethea*, *Geodia*, *Pachymatisma*, *Spongilla*, *Dysidea*, and

Halisarca, and these nine genera are all that are contained in Dr. Johnston's 'History of British Sponges.'

Both of these arrangements are very insufficient, and that of Lamarck completely ineffectual, inasmuch as there is no class of animals in which the form varies to so great an extent, according to the difference of locality or other circumstances; and also even when there is a striking normal form, it is rarely thoroughly developed until the animal has reached its full maturity. According to the practice of Lamarck, even under the most favorable circumstances there are frequently recurring difficulties in the determination of the species by this method, as the same forms are found to be common to a great number of sponges, the internal organization of which are widely different to each other. From these causes it is, that no naturalists with whom I have conferred on this subject have been able to determine with certainty the species of a sponge by the description given by Lamarck in his 'Anim. s. Vert.,' or by those of any other author who has adopted the same method of description, with the exception of, perhaps, a few very striking species.

The division of the Spongiadæ by their chemical constituents may serve very well to separate them into primary groups, but they are far too limited to be applied as generic characters. I have therefore for this purpose rejected both systems, and have retained the latter one for the purpose of forming primary divisions only, and I purpose founding the generic characters principally on the organic structure and mode of arrangement of the skeleton. *Spongilla* differs in no respect from *Halichondria*, as now accepted by naturalists; and the latter, even in the narrow circle of the list of British species, contains at least ten distinct modes of arrangement of the skeleton, each of which is constant and well defined in its character.

It is not my intention to propose the rejection of any of the well-established genera of my predecessors, but to confine each genus strictly within the bounds indicated by the peculiar mode of the structure of the skeleton which exists in that species of sponge which is the oldest-established

and best-known type of the genus, and to refer all others that may distinctly differ from that type to new genera founded on structural principles.

When I commenced in a similar manner a critical examination of the specific characters of preceding authors, and endeavoured to collect and classify them, I found them to be still more indeterminate than those of class or genera; in truth, it appeared that there was scarcely an approach to a distinct terminology to the science, and that the same author frequently designated the same organ, under different circumstances, by a totally different name; I therefore felt it absolutely necessary, before proceeding to the description of new species, to enter into a thorough systematic examination of the organization of the whole of the species within my reach, and to characterise the organs in such a manner as to render the terms I applied to them definite in their meaning and limited in their application; and in pursuing this object I quickly found an abundance of constant and well-characterised forms and combinations of organization, capable of being applied with precision to the purposes of generic and specific descriptions.

I propose, therefore, in the first instance, to characterise the elementary tissues in the following order:

1. Spicula.
2. Keratode or horny substance.
3. Membranous tissues.
4. Fibrous tissues.
5. Cellular tissues.

And, in the second place, to treat of the organization and physiology in the following order:

1. The skeleton.
2. The sarcodous system.
3. The interstitial canals.
4. Intermarginal cavities.
5. Dermal membrane.
6. The pores.
7. The oscula.

8. Inhalation and exhalation.
9. Nutrition.
10. Cilia and ciliary action.
11. Reproduction, ovaries, gemmules, &c.

And to conclude with observations on

The generic characters;
The specific characters; and
On the method of examination.

In my references to the views of preceding writers regarding the anatomy and physiology of the Spongiadæ, I shall endeavour to correct the errors, rather than to point out the authors of them, feeling satisfied that posterity will care as little about the petty angry discussions concerning the facts and opinions of the present period as we do about those of our ancestors; at the same time I shall endeavour to do justice to the industry and research of preceding naturalists, whose errors of omission are entitled to every possible excuse, when we remember the difficulties they laboured under in the course of their investigations, for want of competent microscopic powers with which to work out the organization of the minute and delicate objects of their research, while we are in full possession of all the advantages of the modern improvements of the microscope, giving a pleasure and facility to our investigations that must have been comparatively almost unknown to our predecessors.

THE SPICULA.

The spicula are essentially different in character from the fibres of the sponge, although the latter may be equally siliceous with the former. However closely the spicula may be brought into contact with each other or with siliceous fibre, they do not appear to unite or anastomose, while the fibre, whether siliceous or keratose, always anastomoses when it comes in contact with other parts of its own body or of those of its own species.

In the early stage of their development the spicula appear to consist of a double membrane, between which the first layer of silex is secreted, and in this condition they present an internal cavity approaching very nearly to the size of their external diameter. In this state they readily bend abruptly in any direction without breaking, as may be seen in Fig. 247, Plate XI, which represents a porrecto-ternate spiculum from the termination of one of the radial lines of the skeleton at the surface of *Tethea cranium.* This spiculum has been considerably distorted by pressure on the points of the rays at its apex. The deposit of the silex is not continuous and homogeneous, but is produced in successive concentric layers, which it would appear are, at least for a period, equally secreted by the inner surface of the outer membrane and the outer surface of the inner one; for we always find that as the development of the spiculum progresses, the internal cavity gradually becomes less, until finally it exists only as a central canal of very minute diameter in comparison with that of the spiculum itself. These stages of development may often be seen in the spicula of young specimens of *Spongilla fluviatilis,* especially in the spring, when they are growing rapidly. If small fragments of the sponge be slightly charred in the flame of a lamp, and then submitted to microscopical examination, the outer and inner membranes of the spicula will readily be rendered visible (Figs. 248, 249, Plate XI); in immature spicula the internal membrane is represented by a dense black film of charcoal, as in Fig. 249, Plate XI; while in the mature ones the small central cavity is seen to be lined by so thin a membrane as to afford by its charring a slight brown tinge only to its walls (Fig. 248, Plate XI). The concentric deposition of the layers of silex or carbonate of lime in the spicula are also readily to be seen (Fig. 250, Plate XI) in transverse fractures of almost any large spiculum, either siliceous or calcareous, and they present the same aspect as similar sections of either the prismatic cells of shell tissue or the spicula of a Gorgonia. The amount of silex, and the manner of its deposition in the spicula, is not the same under all circumstances. Where

the spiculum is simply required to give strength and firmness to the skeleton, as in the greater number of the Halichondraceous sponges, the whole interior of the spiculum becomes rapidly filled with silex; but where strength is required to be combined with great elasticity and toughness, the mode of deposit is especially adapted to the requirements of the occasion; the amount of the silex deposited is small, and confined wholly to the surface, while the interior appears to be filled with keratode. These laws of deposit will perhaps be best illustrated by my detailing a series of experiments I made by the incineration of the spicula of various sponges in the flame of a small spirit-lamp. I was led to this series of experiments by frequently observing during the course of my investigations the great amount of flexure that many of the large and long spicula would sustain without fracture, and the perfect elasticity with which they regained their original form and position. Thus, in mounting the spicula of *Tethea cranium* in Canada balsam, the long and slender porrecto-ternate defensive spicula projected from its surface would frequently have the shaft bent in a series of sigmoid curves or even loops; and the thickest portion of the same spicula, while in their natural condition, may be bent down to the surface of the sponge, from which they spring at right angles, so as to form an arc of the third of a circle with perfect impunity. This great flexibility appeared to me to be so incompatible with a purely siliceous structure, that I determined to select the spicula of *Tethea cranium*, more especially to work out this problem, and from the large size of those of the skeleton fasciculi they are more than usually favorable for the purpose. If we view these spicula in their natural condition, mounted in either water or Canada balsam, by transmitted light and a linear power of 150, they present all the usual appearances of solid siliceous spicula; there is a small central tubular cavity, and the substance of the spicula intervening between it and the external surface presents to the eye the linear appearance that characterises a deposit in concentric circles; and the fractured ends have precisely the same aspect that filaments of the same size of

hard dry glue or glass would present to the eye. If these spicula be now burned in the flame of a small spirit-lamp until the combustion is completed and the mass is brought to a white heat, and it be then examined as before, the results are widely different in their aspect; the spicula have become considerably increased in diameter, and instead of being solid, they are now extremely thin tubes of silex, lined with a dense and nearly opake film of charcoal, rough and granulated in its appearance. I thought in the first instance that I might have unwittingly selected a fasciculus of young spicula only, for burning, and I therefore repeated the experiment, burning only half of the fasciculus and preserving the remainder in an unaltered condition; and on carefully mounting the specimen in Canada balsam, I found the same results precisely; the unburned half of the fasciculus presented all the characters of solidity that I have before described, while the burned half was in perfect unison with the previous results of incineration; and at the junction of the two, the transition from the one state to the other might be readily traced even in single spicula. The external coat of silex in these spicula is so thin and the coat of charcoal with which it is lined so rough and opaque, that the thickness of the silex cannot be readily ascertained; but in one of the short, stout, fusiformi-acerate spicula of the dermal coat of the sponge, which is about the same diameter as that of the skeleton spicula, I succeeded in measuring the thickness of the siliceous coat accurately after incineration. The length of the spiculum was $\frac{1}{30}$th of an inch, the greatest diameter $\frac{1}{530}$th of an inch, and the thickness of external siliceous case $\frac{1}{7500}$th of an inch. Figs. 251 and 252, Plate XI, represent portions of two of the large spicula of the skeleton after incineration.

I have very little doubt that the combustible matter in the interior of these large spicula is really keratode, one of the most elastic and durable animal substances with which we are acquainted. The mode of its deposition within these organs is precisely the same with that presented in all the varieties of keratose fibre with which I am acquainted; and from its concentric arrangement, the nature

of the material itself, and its combination with a thin external case of silex, it presents perhaps one of the most admirable natural combinations of strength, elasticity, and durability.

The structure which I have described as prevailing in *Tethea cranium* is not peculiar to that genus. I obtained similar results from the incineration of the spicula of *Geodia M'Andrewii*, Bowerbank, MS., a new and remarkably interesting species. In this sponge there appeared to be a greater amount of silex secreted in the large skeleton spicula than in *Tethea;* while some of them after incineration were resolved into thin shells of silex, others withstood the operation and retained their form; and some were so completely siliceous that, on plunging them into the drop of water for examination while red-hot from the flame of the lamp, the result was the same as if they had been solid glass rods, and these were cracked and shattered in every direction (Fig. 254, Plate XI).

I submitted to the same mode of incineration a few of the long siliceous spicula or fibres of *Euplectella aspergillum*, Owen, burning about half of each fibre, and the result, although somewhat different, was equally satisfactory. The unburned portion appeared perfectly solid, but exhibited the usual trace of concentric structure. The end thoroughly burned became reduced to a thin filament of densely black matter like charcoal, but the junction of the burned and unburned portions were extremely interesting. At this point the action of the heat upon the concentric layers had separated them from each other in the form of a series of thin curved flakes or coats, illustrating the concentric structure in a very satisfactory manner; demonstrating that the outer coat of siliceous matter was not the only one, and that probably there were several coats, each containing a sufficient amount of silex in its composition to resist disintegration by incineration (Fig. 253, Plate XI).

On operating in like manner on the spicula of *Chalina oculata*, Bowerbank, little or no alteration was perceptible in the spicula, the inner cavity remaining the same as in the unburned ones, and distinguished only by a slight

brown tint, indicating the existence of but a very small amount of animal matter within. This result might be expected; the spicula, being imbedded in the keratose fibre to give it additional firmness and strength, are not required to be elastic; they are therefore short, comparatively stout, and solid in their structure.

A specimen of *Halichondria panicea*, Johnston, burned in the flame of a spirit-lamp to a white heat, exhibited no alteration in the mature spicula, in many of which I could not detect a central tubular cavity; and I presume in these cases the spicula were entirely filled with silex, as in younger spicula it was more or less apparent. When the cavity was very small, the colour had a very faint tinge of brown, and, as in other cases, when the cavity increased in diameter, the amount of colouring matter produced by the incineration of the animal matter within became greater and deeper in its tint, until in the young and immature spicula the internal cavity occupied the greater part of its diameter, and it became perfectly black and opaque; and in one spiculum the gaseous matter generated within expanded one part of the spiculum to such an extent as to cause it to resemble exactly a hydrometer in form.

The result of the incineration of *Halichondria incrustans*, Johnston, was very similar to that of *Hal. panicea*. The adult spicula remained unaltered, and the central canal was rendered more apparent than it was before.

On burning portions of *Spongilla fluviatilis* and *lacustris*, Johnston, and of *Spongilla cerebellata*, Bowerbank, I found the results were similar to those obtained from *Halichondria panicea* and *incrustans*, as regards the spicula of the skeleton; but in the small spinous spicula investing the ovaria of the last-named species there was no apparent alteration, nor could any indication of a central cavity be seen.

The calcareous spicula of *Grantia compressa* withstood incineration better than I expected. The surface was studded with numerous little vesicles, generated by the heat, and which interfered with their transparency; but they retained nearly their original colour and proportions, and it

may therefore be concluded that they contained so great a proportion of calcareous matter as to prevent their disintegration by heat.

Many of the forms of the spicula are by no means peculiar to the Spongiadæ; but, on the contrary, as I shall hereafter show, their types are frequently to be found in the more highly organized classes of animals, and especially among the Zoophyta, the Tunicata, and the Nudibranchiate Mollusca. They are always of an organic type, never crystalline or angular.

Each of the elongated forms of spicula may be said to be composed of three parts, the base, the apex, and the shaft intervening between the two; and, generally speaking these parts may be readily determined, even when the spicula are isolated.

Each species of sponge has not one form of spiculum only, equally dispersed throughout its whole substance; but, on the contrary, we find that separate parts have each its appropriate form; and thus we find that three, four, or even more forms often occur in the same individual; and in *Tethea cranium* there are no less than seven distinct shapes. But these differences in structure must not lead us to believe that every strange form of spiculum that meets the eye is a normal one; remarkable variations are often produced for especial purposes in the construction of the skeleton or for other objects; and in some species, *Spongilla lacustris,* for example, the number of malformations that are occasionally found is very remarkable. The size also of the normal forms of spicula will often vary to a considerable extent in the same sponge; but if adult, they are always in accordance with the type form, and if not adult, intermediate states of growth are generally present to assist us to form correct conclusions regarding them. The forms thus appropriated to the different parts of the sponge are not always peculiar to certain species, but, on the contrary, they are frequently found to be repeated in other species differing widely in their construction.

The spicula thus appropriate to particular parts of the sponge are uniform in their general characters throughout

the whole of the Spongiadæ, and a great portion of them, when adult, are so well-characterised by their form as to enable the student, when once well acquainted with their peculiarities, to assign each readily to its proper place in the sponge. In many cases they preserve the same form from the earliest to the latest period of their development, while in others the variations they undergo during their growth are very remarkable. It is therefore necessary that these mutations of form should be carefully noted whenever they are observed, lest they be mistaken for normal ones. Some of the most remarkable changes in form, during the course of their development, will be described under their respective heads.

The spicula in the skeletons of the Spongiadæ appear to be the homologues of the earthy deposits in the bony structures of the more perfectly developed living forms. In the higher tribes of animals we find the disintegrated condition of the earthly deposits in the first stages of the development of the bony structures in the form of minute radiating patches, which in a more advanced stage unite and form the solid mass of bone, as in the mammalian tribes of animals, while in the cartilaginous tribe of fishes these radiating centres of bony secretion never attain a higher degree of development, but remain isolated points of bony structure during the whole of the life of the animal. And in the compound tunicated animals we find the calcareous stellate and sphero-granulate forms of spicula developed in close accordance with the similar siliceous forms in various species of sponges. Thus the stellate and cylindro-stellate spicula of the sarcode in the Spongiadæ are *apparently* the homologues of the bony centres of development in the higher animals. It is so likewise with the other forms of sponge spicula. We find isolated calcareous spicula of an irregular fusiformi-acerate shape, representing the bony skeleton of the higher animals in the outer integuments of several species of *Doris*.

Messrs. Alder and Hancock, in their admirable 'History of the British Nudibranchiate Mollusca,' describe calcareous spicula occurring in *Doris aspera*, *bilamellata*, and *Triopa*

claviger, which *appear* to be analogous to the rectangulated-triradiate spicula of *Grantia;* and they also state that in the first-named species crucial or dagger-shaped spicula occur in the branchiæ and margins of the cloak of the animal, and forms very similar to those occur on the interstitial membrane of *Leuconia nivea*, Bowerbank. Numerous forms of tuberculated and smooth calcareous spicula are also found in the extensive family of the Gorgoniadæ. And the siliceous simple bihamate form of retentive spiculum, so abundant on the interstitial membranes of many species of sponges, are closely represented by the calcareous bihamate spicula so numerous on the tubular suckers of *Echinus sphæra.* Thus we find in the spicula only, a series of links in the chain of animal development, intimately connecting the Spongiadæ with the higher tribes of animals.

In the solid siliceous fibres of *Dactylocalyx* (Fig. 274, Plate XV), and in the tubular siliceous fibres of *Farrea occa*, Bowerbank, MS. (Fig. 277, Plate XV), and especially in the latter, we obtain a very much closer approximation to the tubular forms of the bones of the higher classes of animals.

From our knowledge of the great scheme of the natural development of animal life, the most perfectly organized sponges appear to be those which secrete carbonate of lime as the earthly basis of their skeletons, and the least perfect those which secrete no earthy matter in the skeletons; those which secrete silex taking an intermediate position; but it must also be remembered that there is no form of spiculum found among the calcareous sponges, or in the higher tribes of animal life, that is not repeated among the siliceous forms of spicula of the Spongiadæ.

The spicula may be conveniently classed under the following heads:

1. The essential skeleton spicula.
2. The auxiliary spicula.

The Essential Skeleton Spicula.

In the siliceous sponges they are usually simple, elongate in form, slightly curved, and occasionally more or less fur-

nished with spines. They are either irregularly matted together, collected in fasciculi, or dispersed within or upon the keratose fibres of which the skeleton is to a great extent composed. Occasionally, but not frequently, they assume the triradiate form. In the calcareous sponges, beside the simple elongate form, the triradiate spicula are found in abundance.

All the elongate forms of spicula of the skeleton are subject to extreme variety in length. In some species they maintain a great degree of uniformity, while in others they vary to a very considerable extent, according to the necessities arising from the mode of the construction of the skeleton. When the areas of the reticulations are large, they are generally long and rather stout, and are usually shorter when the proportions of the network are small and close. When enclosed in keratose fibre, they are most frequently smaller and shorter in their proportions than those in the Halichondroid sponges. And in those species in which they are dispersed over the membranous tissues, as in *Hymeniacidon*, Bowerbank, they are generally long, slender, and frequently flexuous. In the sponges of this structure having siliceous spicula the triradiate form of spiculum occurs but rarely, while in the calcareous sponges, which consist of membranes and dispersed spicula, the triradiate forms of skeleton spicula are the normal ones.

When the skeleton is constructed of large fasciculi of spicula, as in *Tethea* and *Geodia*, they attain their greatest dimensions as essential spicula of the skeleton, frequently exceeding the eighth of an inch in length.

The greatest known length of spicula occurs in the prehensile ones of *Euplectella aspergillum* and *cucumer*, Owen, where they are found to exceed three inches in length; and in *Hyalonema mirabilis*, Gray, where in the spiral column of the great cloacal appendage they reach the extreme dimensions of six or seven inches in length; but in both these cases the spicula must be considered as auxiliary, and not essential forms.

The larger number of forms of skeleton spicula are perfectly smooth, but in some species they are partially or entirely covered with spines.

In every case they appear in the living state to have the capability of a change of position within the fibre to a considerable extent, in accordance with the natural alterations arising from the extensions or contractions of those tissues.

The spicula are among the earliest developed organs of the sponge. Dr. Grant, in his valuable "Observations on the Structure and Functions of the Sponge," published in the 'Edinburgh New Philosophical Journal,' vol. i., p. 154, states that spicula are developed in the locomotive gemmules of *Halicondria panicea* (*Hal. incrustans*, Johnston) before they attach themselves for life and commence their development as fixed sponges. And in the gemmules of *Tethea cranium* they are abundantly developed even before the gemmules are detached from the parent, and some of them are forms peculiar to the gemmule.

The growth of the spicula and their mode of extension appears to vary according to circumstances. Thus an acerate spiculum is at first short and very slender; as the development proceeds, it increases in diameter, and appears to lengthen equally from the middle towards both ends; but in spinulate ones the increase in length does not appear to be effected in the same manner as in the acerate form, as we often find spinulate spicula fully developed at the base, while the shaft is exceedingly short and the apical termination hemispherical instead of acutely pointed, as in the adult state. As the shaft lengthens towards its full proportions, it attenuates; but in all the intervening stages the apical termination is usually more or less hemispherical. The progressive development from the base to the apex of the spinulate form is beautifully illustrated in the skeleton spicula of a new and very singular British sponge from Shetland, *Halicnemia patera*, Bowerbank, represented by Figs. 228, 229, 230, 231, 232, and 233, Plate X. Fig. 230 represents a short variety of the normal spinulate form. In Fig. 228 we have a bi-spinulate, and in Fig. 229 a tri-spinulate, form. The latter two are not mere malformations, but they prevail to a great extent in the structures of the sponge, subject to variations in the distances in the development of the second and third inflations from the basal

one. Figs. 231, 232, and 233, represent immature spicula in progressive stages of development, the apices having hemispherical terminations.

Auxiliary Spicula.

Beside the spicula essential to the structure of the skeleton, there are several other forms of these organs, many of which, although not absolutely necessary in the structure of the skeleton, are of very frequent occurrence in subsidiary organs found in particular species and in peculiar genera. They may be conveniently classed under the following heads:

Connecting spicula.
Prehensile spicula.
Defensive spicula.
Tension spicula.
Retentive spicula.
Spicula of the sarcode.
Spicula of the ovaries and gemmules.

In the above designations of the auxiliary spicula, it must not be understood that their respective titles strictly define their offices, as it frequently occurs that under peculiar circumstances the same form of spiculum is destined to serve two, or even three, distinct purposes. Thus, an external defensive spiculum will occasionally perform retentive offices for the purpose of securing prey; or internal defensive spicula will combine the offices of defensive spicula against the larger and more powerful of their enemies with that of wounding and securing their smaller ones.

The Connecting Spicula.

These spicula are not necessarily a part of the skeleton; they are a subsidiary portion of it, occurrring under special circumstances in a few genera only, such as *Geodia*, *Pachymatisma*, and other sponges which have a thick crustated surface, which they serve to support and retain in due

connection with the mass of the animal beneath. The triradiate apices also serve to construct areas in which are situated the proximal orifices of the intermarginal cavities, which are imbedded in the crustated surface of the sponge. The normal form of these spicula is very different from that of the spicula which constitute the general mass of the skeleton, and they are far more complex and varied in their structure. They usually have a long, stout, cylindrical, or attenuated shaft, terminating either acutely or hemispherically at the base, while the apex is divided into three stout equiangular radii, which assume in different species a considerable amount of variety as regards form and direction. The triradiate apices are usually cemented firmly to the inner surface of the crustated coat of the sponge, while the stout and elongated shaft is intermingled with and firmly cemented by keratode to the general mass of the skeleton. From the trifid nature of the apex, I have designated these forms as ternate spicula, prefixing such terms as may best serve to distinguish them individually in accordance with their permanent variations from each other. The prefixed designations of the spicula must necessarily in some measure be arbitrary, as the differences in the degree of the expansion of the radii cannot be strictly defined; and although the forms are well characterised in each species, yet even within these bounds a slight degree of variation, arising from the local necessities of the case, will occur. The ternate spiculum, therefore, as a general designation, may be said to be an elongate spiculum, with a triple apical termination. These spicula are not confined to the office of connecting only, but are also found among the defensive ones, as will be hereafter shown they are best developed in *Geodia McAndrewii* and *Barretti*, *Pachymatisma Johnstonia*, and others of similar structure.

I have never seen the progressive development from a simple elongate shaft of an expando or patento-ternate connecting spiculum, as I have those of the porrecto-ternate external defensive form, and the spinulo-recurvo-quaternate internal defensive ones, but from the great similarity that exists in their structure there can be little doubt that their

mode of growth is the same; and I am very much inclined to believe that the cylindro-expando-ternate form from *Pachymatisma Johnstonia*, Fig. 46, Plate II, is an incompletely developed form of the mature attenuato-expando-ternate spiculum that belongs to that sponge, and which is represented by Fig. 45 in the same Plate.

There is a progression of development in the ternate terminations of these forms of spicula that is very interesting. The simplest form has three nearly straight attenuating radii. In the next stage the distal ends of the primary radii become furcated, but the secondary radii remain in the same plane as the primary ones. In the third stage of development the terminations of the secondary radii again divide into furcations, becoming dichotomo-patento-ternate (Fig. 53), but in this case the radii of the extreme furcations are not all in the same plane, as appears always to be the case with those of the secondary radii, and thus we have produced an additional power for combined action. But in the whole of these varieties, in the structure of these ternate terminations, hitherto there is no appearance, further than their general form, of their being destined to become a united structure, and in some sponges in which they do occur they rarely, or ever do, become thus united; but this demonstration of their destination for combined action is obtained in an irregular ternate form, as exhibited in the dermal structures of a new species of siliceo-fibrous sponge from India, *Dactylocalyx Prattii*, Bowerbank, MS., in which we have the primary radii sinuated and flattened in such a manner as to splice together and form a strong and regular reticulated structure for the support of the dermal membrane of the sponge, as in Fig. 306, Plate XX, which represents a few of these spicula uniting to form the reticulations of the dermal tissues, while Fig. 52, Plate II, represents one of these spicula separated by boiling nitric acid. By this structure, as exhibited in *D. Prattii*, there is rendered apparent a more visible and common purpose in their form and mode of development, and we are gradually conducted to the still more complete and continuous form of fibro-siliceous dermal network that

exists in the beautiful harrow-shaped tissue of the dermal structures of the sponge *Farrea occa*, Bowerbank, supporting the fine specimen of *Euplectella* in the possession of my friend Dr. A. Farre, and described by Prof. Owen in the 'Transactions of the Linnean Society,' vol. xxii, p. 117, plate 21, and which tissue I shall describe more fully in treating on the subject of the dermal structures of the Spongiadæ.

There are two distinct purposes in the physiological application of the ternate spicula; the simplest is that of strengthening and connecting the dermal membrane with the mass of the animal beneath. The second and more complex one, is that of forming an internal reticulating framework for the support within its areas of the valvular tissues forming the bases of the intermarginal cavities. These offices of the ternate spicula are not demonstrated in an equal degree of perfection in all sponges in which they occur. Where the organs which they subserve are best and most abundantly developed, these forms of spicula are found in the greatest quantities, and in the most regular and perfect mode of arrangement, but where the intermarginal cavities or porous areas are in a less regularly developed state, they are deficient in a corresponding degree; thus evincing the design and purpose of their structure and presence. The most perfect and beautiful illustration of their physiological purpose, in their first mode of application, is afforded by the dermal membrane of *Dactylocalyx Prattii*. Here we find their radii, as described above, overlapping each other longitudinally, and cemented together by keratode, forming a continuous and regular network, upon the upper surface of which the dermal membrane reposes, and to which it is firmly united. The mode in which the radii are united, and the material with which they are cemented together indicate a unity of firmness and elasticity in the living state that is truly admirable; and this mode of structure we perceive is especially necessary to the action of the dermal membrane, as the whole of the skeleton beneath is perfectly rigid and inelastic. Thus while their shafts are deeply plunged in, and firmly secured to, the immoveable mass beneath, their

ternate apices are capable of such an amount of oscillating motion, as would be required for the organic expansion and contraction of the membranous structure they support. By the action thus generated each pair of the united radii would glide in a longitudinal direction upon each other, and thus, although in each separate instance the amount of motion would appear to be exceedingly small, the aggregate of the whole would afford a very considerable range of expansion, as exhibited in Fig. 306, Plate XX.

In their second mode of application, that is to the bases of the intermarginal cavities, it appears that as their office is different, so their form, and the mode in which the radii of their apices is connected is also different. Thus at the inner surfaces of the thick dermal crust of *Geodia McAndrewii* and *Barretti*, we find them forming a network equally regular and continuous as that in *Dactylocalyx Prattii*, but the mode of its construction is varied. The radii do not in these cases glide upon each other longitudinally, but they cross each other at various angles; and as the whole mass of these sponges are fleshy and very elastic, so by this mode of interlacement of the radii a very considerably greater amount of expansion and contraction of the reticulated structure is provided for, while at the same time the power of maintaining the common plane of the reticulated tissue is equally as great as in the similar structure in *Dactylocalyx Prattii*. Thus far we can trace the physiological purpose of their structure; but why in one species we find their terminations simple as in *Geodia McAndrewii*, and furcated as in *Geodia Barretti*, or still further complicated as in the dichotomo-patento-ternate form, is a question which cannot be so readily solved without a further acquaintance with the species of *Geodia* bearing these forms in a living state.

Prehensile Spicula.

Spicula projected from a sponge as a means of attachment to other bodies.—I know of but one form of this description of spiculum, an exceedingly elongated, fusiformi-acerate one, with a stout recurvo-quarternate apex. It occurs at

the bases of *Euplectella aspergillum* and *E. cucumer*, Owen. The long attenuated basal portions of the shaft being without spines, are incorporated with the longitudinal fasciculi of the skeleton, while the apical portions of them are projected from the base of the sponge, and embrace and hook on to any extraneous mass near which it may be situated; and this free portion is thickly beset with strong acutely conical spines, reflected at about the same angle and in the same direction as the radii of the quaternate apex, and to which they are auxiliary as prehensile organs; and as we proceed towards the central portion of the spiculum, the spines successively decrease in length, until at about one third of the length of the spiculum from its apex they become obsolete. I am indebted to my friend Dr. Arthur Farre for the specimen figured of this singular and interesting form of spiculum; and the only sponge in which they have been found in a perfect state, is the delicate and beautiful one designated by Professor Owen *Euplectella cucumer*. They occur in great profusion, embracing the mass of matter at its base in every direction. I propose, therefore, to designate this form as an apically spined recurvo-quaternate spiculum (Fig. 59, Plate III: *a*, the apical portion of the spiculum; *b*, a portion from that part of the shaft at which the spines become obsolete).

Defensive Spicula.

There are two classes of defensive spicula:—

1st. Those of the exterior,
2nd. Those of the interior of the sponge.

They are neither of them necessarily present in every species, nor are they confined to particular genera, but occur occasionally, and in certain species of various genera, apparently as the necessities of the animal may render their presence requisite. If the exterior of the animal be amply supplied with them, the interior rarely possess them. Their office is evidently to defend the sponge from the attacks of predacious animals that would otherwise very probably

destroy it; and thus it is that the external defensive spicula are frequently of more than the usual length and strength of these organs. They are projected for about half or two-thirds of their length, at various angles from the surface of the sponge, apparently with the object of meeting the attacks of the larger class of depredators; but as between the large spicula the smaller tribes of annulate animals would readily insinuate themselves, there is frequently a secondary series of defences, consisting of innumerable short, finely-pointed spicula, the *apices* of which are projected a short distance only beyond the surface of the dermal membrane, thus rendering the progress of the smaller and more insinuating enemies extremely difficult, if not impossible. In young sponges, as in *Spongilla fluviatilis* and others, the office of external defensive spicula is frequently performed by the continued extension of the radial lines of the skeleton, the terminal spicula of which often project to more than the extreme length of a spiculum beyond the surface of the dermal membrane.

The arrangement of the spicula, in regard to their especial office in the sponge, can only be approximately correct as we frequently find them applied to what appears to be abnormal offices; thus the stellate forms, which are especially applied to the protection of the sarcodous surfaces of the interstitial membranes of the sponge, are occasionally appropriated as external defences for the preservation of the dermal membrane as in *Tethea muricata*, Bowerbank, MS. (Fig. 35, Plate I). And the connecting spicula so abundant within the crustular dermis of *Geodia* and *Phachymatisma* are frequently, with various modifications of form, applied as externally defensive and as tension spicula in the dermal membrane, as in *Dactylocalyx Prattii*, Bowerbank, MS., as connecting and tension spicula and in the allied form, with the addition of an external spicula ray and the additional office of external defence, as represented by Fig. 55, Plate II, from *Geodia Barretti*, Bowerbank, MS. Similar spicula are found abundantly on the surface of *Dactylocalyx Bowerbankii*, Johnson, in the British Museum. The offensive is so frequently combined with the defence office in the structure of some of these spicula,

and it is so difficult, in some cases, to determine which of the two, or whether both, are designed in the structure of the spiculum, that I have not made a distinction between presumed offices indicated by their structure, but have classed the whole under the designation of the defensive spicula.

When the defensive spicula are internal they usually assume a different character from the external ones. The most common form under these circumstances is that of a short, stout attenuato-acuate spiculum, profusely and entirely spined (Fig. 289, Plate XVII); they are firmly based in the substance of the skeleton; and the greater portion of their length is projected at various angles from the sides of the interstitial canals and cavities of the sponge. They would thus render the passage of minute annelids and other small enemies extremely difficult; and in one instance, the mode in which the protection of the interior of the sponge is provided for is very remarkable and curious. Large spinulo-recurvo-quaternate spicula with attenuating radii are grouped together on the angles of the network of the skeleton, and are projected in a radiating manner into the cavities of the interior of the sponge, forming a most effectual prevention to the passage of any small animal (Fig. 292, Plate XVIII). The occurrence of this complicated and beautiful form of spiculum is a singular deviation from the normal mode of defence, and almost induces the belief that it was intended that such intruders as effected an entrance were meant to be retained, and their decomposed particles appropriated to the nutrition of the sponge. In other cases, where no definite form of defensive spiculum forms a part of the sponge, the office of those organs is frequently performed by the projection of spicula similar to those of the skeleton into the canals and cavities of the interior.

If I were to attempt to enter upon a description of every variation in the mode of the application of spicula to defensive purposes, it would extend this portion of the subject to a greater length than we can afford under the present circumstances. I shall therefore confine my observations to a description of the general principles of

defence as exhibited in some of the principal genera of the Spongiadæ.

In the external defences, the mode of the application of the spicula depends in a great degree on the structure of the skeleton of the sponge. The most simple cases are those where the structure of the skeleton consists of spicula radiating from the centre or the axes of the sponge, and in these cases they usually consist of the terminations of the radial lines of the skeleton, the distal spicula of which are frequently projected for a considerable part of their length through the dermal membranes, and in many sponges the surface is thus thickly studded with them ; and in species where the terminal radial lines of the skeleton contain many spicula, they are frequently found at their apices to assume a radiating direction, so as to present the greatest possible number of points to their external enemies. This mode of defence is very general in the numerous British species of the genera *Isodictya* and *Chalina*, Bowerbank. Fig. 287, Plate XVII, represents a small portion of a section at right angles to the surface from *Chalina seriata*, Bowerbank, illustrating very distinctly this simple mode of external defence.

In the genus *Dictyocylindrus*, Bowerbank, which consists principally of slender branching sponges, many of which in their living state are exceedingly fleshy in their appearance, the skeleton is formed of a central cylinder, composed of a network of spicula, from the surface of which radiate in vast quantities long, slender and acutely pointed spicula, which in the living condition project slightly beyond the dermal membrane of the sponge, so that in the event of any small fish attempting to feed upon or suck this tempting bait, instead of a mouthful of soft and grateful gelatinous matter, he would find himself assailed in every direction with an infinite number of minute points, many of which he would carry away with him deeply imbedded in the soft lining of his mouth, as the reward of his temerity and a warning against a repetition of a like assault. Fig. 365, Plate XXXII, represents a small portion of a young branch of *Dictyocylindrus rugosus*, Bowerbank, frequently found on shells and stones dredged

up at Shetland, or the Orkney Islands. In the genus *Tethea*, in which the skeleton consists of fasciculi of large, stout spicula radiating from the base or centre of the sponge, the system of defence is somewhat more complicated. It is a combination of the terminations of the skeleton fasciculi with, in some species, the addition at the surface of the sponge of porrecto-ternate and recurvo-ternate spicula; the latter two forms being probably aggressive as well as defensive, subserving the purpose of entangling prey as well as that of defence.

This mode of defence is very beautifully illustrated in *Tethea cranium.* Fig. 362, Plate XXXI. The distal ends of the skeleton fasciculi, composed of large fusiformi-acerate spicula, are projected through the stout coriaceous surface of the sponge, and in the midst of this thick coat each of the passing fasciculi is surrounded by a cluster of stout short fusiformi-acerate spicula, their distal points closely embracing the fasciculus, while their proximal terminations are spread widely out in a circle around the lower part of the skeleton fasciculus at *b*, so as to form a strong and most efficient conical buttress to sustain it in its proper position, at the same time allowing a considerable amount of elasticity to meet pressure from without. Each skeleton fasciculus terminates with from two to eight or ten porrecto-ternate spicula, and occasionally we find one or two of the recurvo-ternate ones accompanying them; but their apices are rarely projected much beyond the dermal membrane of the sponge, while the rest of the spicula extend considerably above it. The same system of defences prevails also in *Tethea similima*, Bowerbank, MS., from the Antartic regions; but in this species the recurvo-ternate spicula appear to be protruded in greater numbers, and in more regular order than in our northern species, *T. cranium.*

In *Tethea muricata*, Bowerbank, MS., the skeleton fasciculi are not protruded beyond the surface, but immediately beneath it we find the heads of numerous large furcated expando-ternate spicula, with remarkably long and acute terminal radii, while the dermal membrane is profusely furnished with attenuato-elongo-stellate spicula, Figs. 304 and 305, Plate XIX.

In *Tethea Norvegica* and *Ingalli*, Bowerbank, MS., and in *T. lyncurium*, Johnston, the same protection is attained in a different manner. Instead of the spicula of the skeleton fasciculi gradually converging towards a point, they diverge considerably as they approach the surface, so as to present an infinite number of minute and nearly equidistant points, and in addition to these the dermal membrane and the coriaceous coat of the sponge is supplied with an infinite number of closely packed stellate spicula.

In some species of the genus *Geodia* the system of external defences is still more complex. Thus in *G. McAndrewii* and *G. Barretti* the defences are double, one system consisting of a continuation of the great radial fasciculi of the skeleton as a protection against the assaults of the larger and more powerful assailants; and then of a secondary series consisting of an infinite number of minute acerate spicula, based immediately beneath the dermal membrane and projecting to a slight extent beyond its external surface, effectually protecting it and the porous system of the sponge from the attacks of its minute and more insidious enemies.

Similar modes of external defences exist in various species of *Pachymatisma* and *Ecionemia*, but no two species appear to agree precisely in these respects.

In the genera *Microciona* and *Hymeraphia*, Bowerbank, differing widely in the structure of their skeletons from any of the sponges hitherto described, and frequently not exceeding in thickness the substance of a stout sheet of paper or a thin card, the same principles of defence are carried out, although their structure is widely different from each other. In the first genus, the skeleton of which is formed of short pedestals of keratode combined with spicula, each of the pedestals, which reach nearly to the surface of the sponge, is terminated with a radiating cluster of long curved and acutely-pointed spicula, the apices of which pass through the dermal membrane in every direction, and thus form a most effectual series of external defences, while their shafts beneath serve as the framework of the intermarginal cavities of the sponge (Figs. 368, Plate XXXIII, and 369, Plate XXXIV). In

Hymeraphia, where the sponge is less in thickness than the length of one skeleton spiculum, and where they pass from the basal membrane of the sponge through the dermal membrane, their apices acting as external defensive organs, while their shafts form the essential skeleton of the animal, there is an especial provision for their preservation from injury. Their bases are expanded in the form of large bulbs, so as not only to afford a greater surface for attachment, but to allow them at the same time to act on the principle of a ball-and-socket joint, giving them a more than usual amount of attachment, and a power of yielding in every direction to pressure on their apices from without (Fig. 370, Plate XXXIV). The defence of the surface of the Halichondroid sponges is less apparent, but equally efficacious; the abundantly spiculous reticulations immediately beneath and supporting the dermal membrane, would render attacks of annelids or other small predaceous creatures exceedingly unpalatable.

In the calcareous sponges the spicular defences are exceedingly interesting. In *Grantia compressa*, the distal ends of the great interstitial cells are amply protected by numerous flecto-attenuato-acuate spicula grouped around their porous terminations, with their club-shaped ends curving in every direction over them, but in no degree interfering with the freedom of their inhalant action. In *Grantia ciliata* they are grouped in circles around the distal ends of the interstitial cells (Fig. 345, Plate XXVI), but in this species they are acutely pointed; and when the inhalant system is in a state of repose, they are concentrated at their extreme points so as to form an elongate cone, effectually enclosing and protecting the porous ends of the cells within them; but when the inhalant action is in full activity, their apices recede from each other until they assume the form of a cylinder, and then freely admit the incurrent streams of water, but effectually repel the advances of any dangerous assailant that may attempt an entrance. The distal termination of the cloaca in this species is also abundantly protected by a marginal fringe of long and very acute spicula, and is furnished with the

same simple but beautiful mechanical contrivances for opening and closing in accordance with the necessities of the animal. For a more complete description of the anatomy and physiology of this highly interesting species I must refer my reader to the 'Transactions of the Microscopical Society of London,' vol. vii, p. 79, pl. v.

In other species of *Grantia* the same principles of external defensive action exists, but the precise mode is never exactly the same in any two species.

Their external defences are the homologues of those of the dermis of some of the *Holothuriadæ* and of *Synapta*. Thus in *Cucumaria communis* we have the dermis furnished with an infinite number of beautiful perforated circular plates, from the centre of each of these is projected outward a spiculated umbo terminating in numerous acute points; when the animal is irritated the whole of these are projected from the dermis and the surface becomes bristling with an infinite number of minute organs of defence. In like manner *Synapta* is furnished with numerous anchor-shaped spines which lie parallel to the dermal surface while the animal is in an unexcited state; but when irritated a muscular contraction of the dermis takes place, the shank of each anchorate spine is drawn inward, forming a minute pit or depression, so that it becomes erect, and the sharply pointed flukes, if we may so term them, are brought into defensive position over the whole surface of the body of the animal.

Internal Defensive Spicula.

The internal defensive spicula of sponges are exceedingly various in their forms and modes of application to their especial purposes; and they seem naturally to resolve themselves into three distiuct groups:—1st, those which are destined simply to repel; 2nd, those which wound and lacerate as well as repel; and 3rd, those which are calculated not only to destroy but also to retain intruders.

The purposes of the first class of spicula are frequently performed by the ordinary spicula of the skeleton, which are projected more or less into the cavities immediately

within the oscula and other spaces requiring such protection; but when especially formed for and appropriated to defensive purposes, they are always free from spines and usually terminate acutely; and they are frequently provided with widely extended basal radii, so as to fix them rigidly and firmly in their proper positions, as exemplified in the various forms of spiculated triradiate spicula represented by Figs. 85, 86, and 87, Plate IV.

The best illustrations of the application of the simple defensive spicula are to be found in the cloaca in several species of *Grantia*, as in *G. ciliata*, Johnston, and *G. tessellata* and *ensata*, Bowerbank, MS. In all these species this great central cavity is abundantly furnished with spiculated triradiate spicula, which are so disposed that while the basal radii are firmly cemented on the surface of the cloaca, the spicular or defensive rays are projected from its surface, not at right angles to its plane, but always at such an inclination towards the mouth of the cloaca as to present a combined series of sharp points in the best possible position of defence, so that an intruding assailant could scarcely escape being seriously wounded by them, while a retiring enemy would pass with impunity over their inclined apices. In some species, as in *G. tessellata*, the defensive ray is naturally curved to the desired angle for defence (Fig. 86, Plate IV), and it is also of such a form as to be readily released from the creature it has wounded, either by being attenuato-acuate or ensiform, as in Fig. 85, Plate IV, from *G. ensata*, and as represented *in situ* by a small portion of a longitudinal section of the cloaca of a specimen of *Grantia tessellata* in Fig. 286, Plate I, in which the defensive radii are all curved in the direction of the mouth of the cloaca.

In the second division the internal defensive spicula are usually short and straight, and more or less covered with strong conical acutely pointed spines, projected either at right angles to the axis of the spiculum, or recurved considerably towards its base; generally speaking the spines are dispersed on all parts of the spiculum without any approach to order, as represented in Fig. 66, Plate III,

while in other cases, as in Figs. 67 and 68 in the same Plate, they are arranged in verticillate order on all parts of the spiculum. In each of these varieties the bases of the spicula are usually profusely furnished with spines so as to ensure a strong and somewhat rigid mode of attachment.

There is undoubtedly a special purpose in every variation of the spination of these spicula, and in their presence generally. The short strong form and acute distal termination admirably adapts them to encounter the larger description of intruding annelids, the most dangerous internal enemies of the Spongiadæ; while the spination of their shafts presents a series of minute weapons that would prove equally formidable to those intruders that were too minute to be affected by the larger weapons of defence.

The acuate entirely spined defensive spicula are of very common occurrence in sponges, and are by no means confined to particular tribes or genera. As a general rule, when the external defences are very full and sufficient, we should not expect to find the internal defences abundant, and, on the contrary, when there appears to be a paucity of external defences, the internal ones are frequently exceedingly numerous. Thus, in the genus *Dictyocylindrus*, Bowerbank, where in almost every species the surface of all parts of the sponge is bristling with the acute terminations of the radiating external defensive spicula, although in most of the species we find acuate entirely spined internal defensive ones, yet in many of the species they are so rare as to be by no means readily detected.

When the skeleton is formed of keratose fibres, we find them dispersed on their surface without any approach to order, and projected at every imaginable angle. If the skeleton be formed of any of the varieties of spiculous reticulations, they are based in a similar manner on the principal lines of the reticulated structure, and sometimes, but not very frequently, they occur in groups.

I will not extend this portion of my subject to an

unnecessary length by describing every mode of their occurrence, but select a few of the most interesting cases as illustrations of the general principles of their application.

Fig. 288, Plate XVII, represents a small portion of the kerato-fibrous skeleton of an Australian sponge, with the attenuato-acuate entirely spined internal defensive spicula *in situ*. Fig. 289, represents a few fibres from a kerato-fibrous sponge from the West Indies, in which the verticillately spined internal defensive spicula are dispersed over the fibres; and Fig. 290 represents the same description of defensive spicula from a West Indian kerato-fibrous sponge, having the defensive spicula congregated in bundles. Sometimes, but not very frequently, they are found on the interstitial or basal membranes of the sponge, and under these circumstances many of them are prostrate in place of being erect; and in one sponge, *Hymeniacidon Cliftoni*, Bowerbank, MS., a singular parasitical species from Freemantle, Australia, this prostration appears to be effected by an especial law. This singular sponge envelopes several fan-shaped portions of a *Fucus*, and systematically appropriates the minute ramifications of its stem to the purposes of an artificial skeleton; the whole sponge abounds with short stout attenuato-cylindrical entirely spined internal defensive spicula; but the remarkable circumstance attendant on their presence is, that where-ever the membranes supporting them envelope and firmly embraces a portion of the vegetable stem, they assume an erect position, and exhibit all the usual characters of defensive spicula; but where the membranes merely fill up the areas of the vegetable network, they are nearly all of them perfectly prostrate and apparently performing the office of tension, rather than of internal defensive spicula. Their form also is singular, being attenuato-cylindrical. not having the acute termination that is usual in this description of spicula.

Fig. 291, Plate XVII, represents a small portion of the fibrous stem of the *Fucus* coated by the membranes of the sponge, and covered with spicula; those immediately over

the stem being erect, while those on the membrane are prostrate. (*a*) represents one of these new form of internal defensive spiculum $\times 175$ linear and (*b*) a small portion of the surface of the *Fucus* showing its cellular structure $\times 400$ linear.

In *Hymeraphia stellifera*, Bowerbank, an exceedingly thin coating British sponge, the internal defensive spicula present a singular variation from the normal form. In this case they assume the shape of an ordinary Florence oil flask, with a somewhat elongate neck, and having a beautiful star-shaped apex in place of a stopper. They occur in considerable quantities; their large bulbous bases are firmly attached to the strong basal membrane of the sponge, and they are projected thence at every possible angle upward into the interstitial spaces. Their apices are crowded with stout acutely conical spines, which radiate in all directions. Fig. 730 *a*, Plate XXXIV, represents a group of these spicula *in situ*, elevated by a grain of sand beneath the basal membrane; and Fig. 34, Plate I, one of the same form of spiculum, magnified 260 linear. In this form of spiculum, as in that of *Hymeniacidon Cliftoni*, their purposes seems to be the infliction of laceration, rather than that of destruction by deep wounds. In another species of *Hymeraphia*, *H. clavata*, these spicula have the same large bulbous bases as those of *H. stellifera*, but their apices are acute, like those of the normal forms of such spicula. In all these cases we observe in their attachments the same approximation to the structure of the ball-and-socket joints of the higher tribes of animals, rendering them capable of yielding in every possible direction to the struggles of any enemy with whom they may be entangled.

In the third division of the internal defensive spicula there is an especial construction for retention as well as for destruction. Their apices are usually more or less hamate, as represented in Figs. 76, Plate III, and Figs. 81 and 82, Plate IV, and their attachments to the sponge are usually such as to allow of a considerable amount of flexibility or motion.

I will not attempt to describe the whole of the numerous variations in the modes of application to defensive purposes, but select a few of the most interesting cases as illustrations of the general principles of combined internal defence and aggression.

The spinulo-recurvo-quaternate spiculum (Fig. 76, Plate III), presents an admirable illustration of the combined defensive and aggressive character of some of those internal defensive spicula. The sponge in which they occur belongs to the Halichondroid tribe, the skeleton being composed of a network of spicula cemented together by their apices, which cross each other at the angles of the areas of the reticulations. The recurvo-quaternate spicula are not dispersed on all parts of the skeleton, but are congregated in groups, frequently consisting of as many as fifteen spicula, the whole of their bases being concentrated on one of the angles of the reticulations of the skeleton, while their shafts and apices radiate thence in every direction into the interstitial spaces of the sponge; they are thus placed on the strongest and most elastic portion of the skeleton, with their hemispherical bases firmly imbedded in the cementing keratode of the skeleton, which abounds at the angles of the network, and which by its inherent elasticity and strength renders the insertion of the base of the spiculum, in strength and extent of action, quite equivalent to the powers of the ball-and-socket joints in the higher tribes of animals. A small annelid or other minute intruder entangled amidst these numerous sharp hooks would struggle hopelessly in such a situation, as the spicula, from the nature of their attachment, would yield readily to its struggles in every possible direction, and at every new contortion arising from its efforts to escape it would inevitably receive a fresh series of punctures and lacerations.

Fig. 292, Plate XVIII, represents a small portion of the skeleton of the sponge bearing the spinulo-recurvo-quarternate spicula *in situ*.

The gradual development of this form of spiculum is interesting and very instructive. In an early stage of

its development it has the appearance of a slender inequibiclavate cylindrical spiculum (as represented in Plate III, Fig. 73); in the next stage there is a slight indication of the spinulate base, and a corresponding amount of expansion of the apex, but no indication of the radii (Fig. 74). From this state to the next well-marked stage of growth (represented in Fig. 75) the progressive development of the radii may be readily traced, and thence to the adult condition represented in Fig. 76.

In its fully-developed state we find a great increase in its size in every respect; the base becomes fully developed and globular, and the radii elongated to a very considerable extent.

In other instances, where defence alone appears to be contemplated, we do not find these beautiful adaptations for motion in every direction prevail. The bases of the spicula in those cases are abundantly spinous, and are evidently intended to maintain a firm hold by their attachments, and are destined rather to rigidly maintain their position than to yield to any struggling body with which they may be in contact. The numerous spines with which these shafts are frequently covered are calculated to wound and lacerate, rather than to retain the enemies with which they are engaged.

I have received from my friend, Mr. J. Yate Johnson, of Madeira, a new and very illustrative instance of the combination of defence and aggression in the structure and offices of the internal defensive spicula; and in this case it is not a new organ, but an adaptation of a well-known form to a new purpose, in the shape of a contort trenchant bihamate spiculum of unusual size and structure. In the course of my examination of the results of the deep-sea soundings in the Atlantic, I found several of these spicula, and was much interested by the singularity of their structure, which at that time I could not comprehend.

The general outline is much like that of the type-form so commonly found imbedded in the sarcode, but it is somewhat less flexuous in its curves, and the shaft and hami are very much larger and stouter than those of the

spicula of the sarcode. But the most singular point in their structure is, that while the curved portion of the hami and the middle of the shaft are perfectly cylindrical, the inner portion of the hooks and those parts of the shaft immediately opposed to them present sharp trenchant edges, so that each hook assumes to some extent the form of spring hand-shears. The acute termination of the hook and the opposed trenchant edges exhibit every facility for effecting an entrance through the tough skin of the victim, while the perfectly blunt and cylindrical state of the arch of the hook bespeaks the design of retention as well as of destruction. As soon as the hook has penetrated to the inner blunt surface of the curve it no longer cuts, and the prey wounded in every direction is securely retained for the nutrition of the sponge. This result is not indicated only by the form of the spiculum; their position in the structure of the sponge bespeaks their office equally unmistakably. They are not immersed in the sarcode like their congeners in form, but are firmly cemented by one hook to the reticulating lines of the skeleton, while the other ends are projected at various angles into the interstitial cavities of the sponge in such numbers and in such a manner, that it would be next to impossible for an intruder within the sponge to escape being entangled and destroyed amongst them. Fig. 293, Plate XVIII, represents a portion of the reticulated skeleton of the sponge with the trenchant contort bihamate spicula *in situ*, magnified 50 linear; and Fig. 112, Plate V, one of the spicula, magnified 400 linear, to exhibit the trenchant edges and the cylindrical portions of the hami and shaft.

This sponge is allied to *Hymedesmia* by the structure of the skeleton, and it is described by my friend, Mr. J. Yate Johnson, as being a thin coating species spreading over the surface of rocks and stones to the extent of two or three inches in diameter.

In *Hyalonema mirabilis*, Gray, a sponge nearly related to the genus *Alcyoncellum Quoy et Gaimard*, we find another extraordinary series of internal defences; one portion of

the spicula appearing to be destined to wound and lacerate, rather than to retain intruding enemies, while a larger and stronger series of spicular weapons bear all the evidences of being to retain rather than to repel the assailants.

The first description of spiculum I have designated entirely spined, spiculated cruciform spicula. They consist of a short stout cruciform base with a long spicular ray, ascendingly and entirely spinous, projected at right angles from the centre of the basal radii. The spines are acutely conical, and very sharply pointed. They pass off from the spicula ray at an angle of 12 or 15 degrees in the direction of its apex. The apices of the basal radii are attenuated and slightly spined. These spicula are thickly distributed on the fasciculi of the skeleton, and frequently equally so on one side of the interstitial membranes, probably that which forms the surfaces of the interstitial spaces, and they are especially abundant near the exterior of the sponge. The four basal radii appear firmly cemented to the membrane, but not immersed in its substance, as they do not appear to leave their impressions when removed from it, nor do they bring any portion of the membrane away with them. In some parts of the tissue these spicula are very much modified in form. In the ordinary cases we find the basal radii short and stout, and not more than a fourth or a fifth of the length of the spicular ray, while in other cases the basal rays are very nearly as long as the spicular one; the only difference in their structure being that the latter is very strongly spinous, while the former have the spines comparatively very slightly produced.

The second form is a large fimbriated multihamate birotulate spiculum, which occurs dispersed amid the interstitial tissues of the large basal mass of the sponge. There are usually not more than one or two together, but occasionally they occur in groups of ten or twelve, without any approach to definite arrangement.

These spicula are comparatively large and stout. They have eight rays at each end of the shaft; the two groups of

radii curving towards each other to such an extent that each forms the half of a regular oval figure; the opposite apices being separated to the extent of about the length of one of the radii. Each ray is in form like a double-edged blunt-pointed knife, bent near the handle in the direction of a line at right angles to one of its flat sides; and each ray is strengthened and connected with the shaft of the spiculum by a stout curved web of silex, which extends from a little below the inner surface of the ray to a point on the shaft about opposite to its middle. The shaft is cylindrical, and has short stout tubercles dispersed over all its parts when fully developed.

The structure of every part of this singularly beautiful spiculum is strikingly indicative of its office in the economy of the sponge; the form and mode of bending of the radii, with their thin edges at right angles to the line of force in a struggling animal, and the powerful web at the base of the ray enabling it to sustain an amount of stress that the unsupported flat ray would never otherwise be able to endure.

The spiculated cruciform spicula are exceedingly abundant in every part of the sponge, and no victim entangled and retained by the large multihamate spicula could avoid innumerable wounds while struggling to effect its escape; while the one held it secure within the sponge, the others, from the peculiarity of their form and mode of the disposition of their acutely pointed spines, would readily release it after the infliction of every puncture, only that the wounds might be multiplied until the creature was pierced in every part, and bled to death for the nutrition of the sponge.

Fig. 294, Plate XVIII, represents a small portion of the skeleton of the sponge with the two forms of defensive and aggressive spicula *in situ*, magnified 50 linear. Fig. 60, Plate III, represents one of the multihamate bihamate spicula with a power of 83 linear, displaying the adaptation of its structure to purposes of retention. Fig. 295, Plate XVIII, represents one of the spiculated cruciform spicula magnified 175 linear, on the same scale as Fig. 60, Plate III, showing their relative proportions.

It would be almost an endless task to describe every variety of those singularly beautiful contrivances for combined defence and offence in the interior of the Spongiadæ. Those which I have particularised are some of the most elaborate and beautiful that I have seen during the course of my researches. In many other cases, where all that is required is defence, the means employed are of a much more simple nature. We find in the Spongiadæ, as in other animals, that nature frequently economises her means by the conversion of one organ to the purposes of another by slight adaptations or additions; thus in *Halichondria incrustans*, Johnston, and in other sponges, the skeleton spicula are made to perform the duties of internal defensive spicula, by being more or less furnished with spines, as represented in Fig. 28, Plate I, and in other cases where we find them medially or apically spined, as in Figs. 30 and 32 of the same Plate.

In like manner we find the spicula of the sarcode, by the extreme profusion in which they occur in that substance near the surface of some sponges, are turned to good account for the general purposes of external and internal defence, as well as for their special purpose of protection and support of the sarcode. So likewise in the tension spicula of *Spongilla lacustris* (Fig. 90, Plate IV,) they are made to serve as defensive organs as well as tension spicula; and, again, in the spicula of the ovaries of the Spongiadæ their skeleton spicula also perform the office of defensive as well, as represented by Figs. 203 and 204, Plate IX.

As regards, then, their protection from their enemies, there appears to be almost a natural prohibition to the sponges becoming, to any great extent while alive, the food of other creatures. The keratode of their skeletons appears to be almost indestructible by maceration or digestion, and the abundance of the acutely pointed spicula that exists in so many of their bodies must render them anything rather than desirable or digestible food to the generality of other marine animals; and in truth I do not know of a single large fish, or other marine creature,

that appears to prey upon them. The only animal in the stomach of which I have ever seen the spicula of any sponge was a *Doris*. But although appearing to enjoy almost an immunity from the common lot of animals, that of being eaten by others, they may yet serve at their death by natural causes to supply an immense quantity of animal molecules for the sustenance of the myriads of minute creatures that exist around them.

Spicula of the Membranes.

There are two distinct classes of spicula appropriated to the membranous tissues of sponges. The office of the first of these is simply to strengthen and support those delicate tissues when necessary, and to communicate to them a certain amount of tension when it is required. The forms are few in number, and their structure comparatively simple.

The office of the second class is that of assisting in the retention and protection of the sarcode on the interstitial and other membranous structures. They are usually minute in size, and often very complicated in form.

I propose to designate these organs as—

1st. Tension Spicula.
2nd. Retentive Spicula.

Tension Spicula.

In some species of sponges the dermal membrane is without spicula especially appropriated to it, and it then appears, as in *Spongilla fluviatilis,* to be a simple translucent membrane filling up all parts of the network of the external surface of the skeleton, and closely adhering to it; but the membranous areas thus formed are devoid of peculiar forms of spicula. In other cases, as in *Spongilla lacustris,* we find spicula dispersed more or less abundantly over the whole of the surface of the membrane, which are entirely unconnected with the skeleton, and give to the dermal membrane a degree of firmness and tension that it would

not otherwise possess. These spicula are sometimes of the same form as those of the skeleton, as in *Halichondria panicea*, Johnston, where we find them thickly, but irregularly dispersed on the inner surface of the dermal membrane. In some cases they are not readily to be distinguished from those of the skeleton, as they are frequently so nearly of the same size, and are intimately intermingled with them, as in the genus *Hymeniacidon*; but in others, as in some species of *Chalina* and *Isodictya*, they may be distinguished by their position, and by the total absence of keratode around them, while those of the skeleton are always more or less coated by that substance.

In other species they differ materially in form and proportion from those of the skeleton. Thus in *Halichondria incrustans*, while the skeleton spicula are stout, short, entirely spined and acuate, as represented by Fig. 28, Plate I. The tension spicula are smooth, slender mucronato-cylindrical, as represented by Fig. 92, Plate IV. They are frequently dispersed on the dermal membranes, much in the same manner as they are on the interstitial ones, abounding most where the areas are largest, and where the areas are small they are few in number or entirely absent; but in other cases, as in the dermal membrane of *Halichondria incrustans*, they are congregated in flat broad fasciculi, which are disposed on the membrane with little or no approximation to order.

In the interstitial membranes the same object is frequently attained by the incipient skeleton spicula, and we often find either very young and minute skeleton spicula in the membranous areas of the network of the skeleton, or there will be one or more spicula very little less in size than those of the skeleton, imbedded in the surface of the membrane, but quite unconnected with the surrounding skeleton; or occasionally connected by one termination only, but ultimately by the development of other spicula, becoming incorporated with, and forming part of the skeleton. And it is not in the Halichondraceous sponges only that the tension spicula occur, for we find them abundantly dispersed in the dermal membrane of one of the Turkey

sponges of commerce, the honeycomb sponge of dealers, in which siliceous spicula play a very subordinate part in the construction of the skeleton.

The tricurvo-acerate form in all its varieties is better calculated to effect their peculiar office in small and irregular spaces, and with greater economy in numbers, than the straight elongated forms, and they are also better adapted to membranes having unequal surfaces, such as those in *Microciona armata*, Bowerbank, where we see them following the undulations of the membranes and sustaining them in their proper positions around the columnar parts of the skeletons. The varieties of form in these spicula are well represented in Figs. 96, 97, and 98, Plate IV. They are all out of the same sponge. In *Grantia compressa*, and other closely allied species, where the structure is systematically membranous, the skeleton spicula are triradiate, supporting the membranes in uniform planes in the most effectual manner; and they are in fact systematically tension spicula, as well as skeleton ones. In *Leuconia nivea*, Bowerbank, which is not symmetrical in its structure, like *G. compressa* and its congeners, other forms of tension spicula are developed to suit their especial purposes, such as represented by Figs. 100 and 101, Plate IV.

In siliceous sponges we also occasionally find triradiate spicula developed and performing the office of tension spicula in the midst of comparatively large membranous areas; but these forms, in every case under such circumstances in which I have seen them *in situ*, appear to belong to the exception, rather than the general rule obtaining in such sponges.

The foliato-peltate spicula—for a full account of the progressive development of which I must refer to Terminology, number 102—appear to be a development of the apices of connecting spicula into dermal tension ones, bearing a strong resemblance in form and purpose to the bony scutes in the skins of some of the higher animals; while the extreme crenulation of their margins probably served the purpose of facilitating the action of the porous system.

In all the varieties in form which I have hitherto de-

scribed, and with which I am acquainted, where they perform the office of tension spicula only, they are destitute of spines. In other cases the tension spicula not only fulfil their own especial office, but they subserve that of defensive spicula also. Thus in the dermal membrane of *Spongilla lacustris*, Johnston, we find them dispersed rather numerously, covered with short acutely conical spines, as represented by Fig. 90, Plate IV. In *Spongilla alba*, Carter, we find the tension spicula as abundantly spinous as those of *S. lacustris*, but in this case the spines are truncated (Fig. 91, same Plate). They have a similarly blunted imperfectly produced character in those of *Pachymatisma Johnstonia*, as represented by Fig. 93.

The production of tension spicula in the membranes of the Spongiadæ is by no means a peculiarity of that class of animals. We find them in numerous beautiful forms in the skins of the Holothuriadæ, varying in shape in the different parts of the animal to adapt themselves to the necessities of their situation; but the closest approximation, both in size and form, to those of the Spongiadæ are the bihamate ones that are found so abundantly dispersed on the membranous tubular suckers of *Echinus sphæra;* and I have also seen another variety of these spicula in the tubular tentacles of a large common species of *Actinia;* and in the latter case they were even more minute than those of the Spongiadæ.

Retentive Spicula.

1st. *Bihamate Spicula.*

In the interior of the sponge we find a series of retentive organs in the various forms of bihamate and anchorate spicula, which exist in large numbers attached to the surfaces of the interstitial membranes. The simplest forms of spicula of this kind are those of the bihamate, in which we have an acerate form of spiculum, bent near each termination into the shape of a hook, the curves being either in the same plane or at right angles to each other, and the terminations being attenuated and acute.

The variety in the amount of curvature at the middle of the shaft of the spiculum is also very great, as represented in Plate V, Figs. 109 to 121; but these variations are not purely accidental; on the contrary, they are more or less constant in each species of sponge, and frequently afford good specific characters.

In the simple bihamate form, where the two hami are curved in the same plane and towards each other, the spiculum, in its natural condition, is usually attached to the surface of the membrane by the middle of the back of the curved shaft, and the two hooks are projected into the sarcode at right angles to the plane of the membrane on which it is based. When the hami are developed reversed or at right angles to each other, one of them is then usually imbedded sideways on the membrane, and the other with the shaft is projected from the plane beneath into the sarcode at various degrees of angle. Or in the deflected form the shaft may be firmly cemented to the membrane by one side, while the hami are both projected upward into the mass of sarcode. In some species of sponge one or the other of these forms especially prevails, but in others, as in *Halichondria incrustans*, Johnston, the simple, reversed, and contort forms are indiscriminately mixed in the tissues, and they occur in every imaginable form of attachment in great profusion, and accompanied by the anchorate forms as well.

However varied they may be in form, when they are in their normal positions their office appears to be purely retentive. They are generally produced singly, and are dispersed without any approach to regularity over all parts of the sarcodous membranes of the sponge, abounding in some situations to a very much greater extent than in others. Their positions on, and mode of attachment to, the membrane are exceedingly varied, but in almost every instance it is such as to render the spiculum obviously subservient to the retention of the sarcode on the membranes which it covers. In one instance only I have found the simple bihamate spicula congregated in loose fasciculi. In this sponge, a new and very interesting species,

Hymedesmia Zetlandica, Bowerbank, they occur in great profusion. Very few of them occur singly; nearly the whole of them are found in rather loose fasciculi, and the number is generally so great in each as to render it very difficult or impossible to count them. The mode of their disposition in the bundles is symmetrical, all the hami being in the same plane and coincident in direction, as represented in Fig. 296, Plate XVIII, bundles of reversed bihamate spicula was observed, and these in like manner were coincident in every respect like the simple bihamate ones.

The type of this form of spiculum, the simple bihamate, is not peculiar to the Spongiadæ; it occurs in a much more highly organised class, in a radiate animal, *Echinus sphæra*, Forbes, 'British Starfishes,' where we find an abundance of these organs disposed on the external surface of the tubular suckers of the animal, but they are composed of carbonate of lime instead of silex. I am indebted to my friend, the late Mr. John Howard Stewart, for my knowledge of this interesting fact.

From the simple bihamate forms there appears a progressive development through the uniclavate and biclavate forms represented by Figs. 118, 119, and 120, Plate V, and the unipocillate and bipocillate forms represented by Figs. 123, 124, 125, 126 and 127, Plate V, to the fully developed anchorate forms of spicula.

In the simple form of pocillated bihamate spicula, the terminations of the curved shaft resolve themselves into two nearly equal, circular, concavo-convex plates, the convex surfaces being in each case outward, and the sides of each plate curving considerably towards the other, their planes being at a right angle to the axis of the shaft. In other cases, one cup will be developed with its plane in the same direction as the axis of the shaft, while the other cup is produced with its plane at right angles to the axis, and also of the plane of the first cup. In these variations of development, therefore, this form of spiculum may be compared to tne simple and contort forms of bihamate spicula; and in truth they differ from them only in this,

that in the one the terminations of the hami are attenuated and acute, and in the other they are expanded into concavo convex discs.

These two modes of development appear to be subject to a considerable amount of variation in the growth of the terminal discs; as in some cases we find the distal part of the terminal plate to consist of a uniform curve, while in other cases the shaft is carried through the centre of that curve, forming, as it were, a supplemental hook. These variations are in perfect accordance with the general laws of development in this class of spicula, as we find, both in the bihamate and anchorate forms, a considerable amount of difference in the structure and position of these organs in the same species of sponge.

A similar organic relationship appears to exist between the umbonate forms of bihamate spicula represented by Figs. 115, 116 and 117, Plate V, and the eccentric trirotulate forms represented by Figs. 133 and 134, Plate X.

2nd. *Anchorate Spicula.*

The anchorate spicula, unlike the bihamate forms, appear never to occur reversed or contorted, but always to present their terminations in the same position as those of the bow of an ordinary ship's anchor. In some sponges they are tolerably uniform in shape and proportions, while in others they vary exceedingly, not only while in course of development, but even in their adult condition; they glide so insensibly from one form into another that it is difficult to draw a distinction between them; and yet, notwithstanding this latitude in shape and development, they are very characteristic of species, as there are always a sufficient number of fully developed ones that exhibit the normal form.

In almost every case of their occurrence, beside the large and fully developed organs, we find a secondary series accompanying them, which are very much smaller in size, and vary exceedingly both in symmetry and amount of

development; and there is every appearance that they are simply abortive developments of the larger and more perfect organs, with which they always appear to agree in their normal characters.

There are two primary divisions of these forms of spicula,—equi-anchorate, when both terminations are produced to an equal extent, as in Figs. 140, 141 and 142, Plate VI, and inequi-anchorate, when the distal termination is largely and fully developed, while the proximal one is, comparatively, produced to a very limited extent, as in Figs. 137 and 138, Plate VI, each of these is subject to a certain extent, to similar degrees of further diversity of form, which may be designated bidentate, tridentate and palmate. These forms are in truth but different degrees of development of the normal palmate form; but as we find these variations constant in different species of sponges, it is desirable that they should be separately designated, as they afford excellent specific characters. Thus in *Halichondria granulata*, Bowerbank, we find large equi-anchorate spicula, in which the lateral expansions of each end of the curved shaft or bow which forms the palmate terminations of the spiculum extend along the shaft towards the middle of the bow, very little beyond the point of curvature forming the basal commencements of the hooks; but although not decurrent on the shaft, the lines of the inner margins are projected forward at an angle of about 45 degrees to the axis of the shaft; and as the outer lines are projected in a corresponding degree, we have the palm produced in the form of two concave conical teeth or palms at each end of the spiculum; and between these there is not the slightest appearance of the ends of the hami, which appear to be equally divided between the terminal palms or teeth. This form I therefore term bidentate equi-anchorate. The same termination occurs among the inequi-anchorate forms; and this mode of the development of the teeth is well shown in the distal or larger portion of the bidentate inequi-anchorate spiculum, represented in Fig. 137, Plate VI. In other cases the termination of each hook does not thus merge in the teeth, but is carried forward between

them either in the form of a simple attenuated termination, as represented in Fig. 140, Plate VI, or it expands laterally and forms a third intermediate tooth of a hastate form, as represented in Fig. 147, Plate VI. In either of these cases I therefore designate the spiculum as tridentate. In other cases, the lateral expansions forming the palm are continued along the shaft of the spiculum to nearly, or quite, the full extent of the palm, forming a single, undivided, more or less concave termination, as in Fig. 138, Plate VI. I propose, therefore, to designate this form as palmato-anchorate; and intermediate forms between the decidedly dentate or palmate ones would be designated as tridentato-palmate (Fig. 138, Plate VI), the palmate form being in excess of the dentate structure; or palmato-tri or bi-dentate, when the teeth are in the ascendant.

Generally speaking, the ends of the shaft of each anchorate spiculum either become obsolete at the base of the teeth, as in bidentate forms, or they are continued in a regular curve, forming the third tooth, as in the tridentate form; but in some cases, as in *Halichondria plumosa*, Johnston, the shaft appears to terminate abruptly at each end, and the palms or teeth are projected towards each other at a sharp angle to the ends of the shaft or bow of the spiculum: in this case we should term the spiculum angulated anchorate, as represented in Figs. 141, 142 and 143, Plate VI.

The anchorate spicula are not, like the acerate, acuate and other simple forms, of the same shape, or nearly so, from the commencement to the termination of their growth, but, on the contrary, they are developed progressively.

In a new species of *Halichondria*, for which I am indebted to my late friend, Mr. Thomas Ingall, the course of their development is displayed in a very interesting and instructive manner. The first condition in which we detect them is in the form of an exceedingly slender and elongated simple bihamate spiculum, which is readily distinguished from the true bihamate form by the straightness of the shaft, the comparative shortness of the hami, and

the obtuseness of their terminations, as represented in Fig. 144, Plate VI. We next find the same form increased in strength, and with slight lateral fimbriæ near each end of the shaft at the commencement of the hami, as in Fig. 145, Plate VI. In a more advanced state we find a regularly curved extension of the fimbriæ, slightly so at one extremity of the shaft, and considerably so at the other; and as the development progresses, the curves of the fimbriæ are extended in an outward direction, and become angular; the extremities of the hami expand laterally and assume a foliated appearance, as seen in the distal or larger end especially (Fig. 146, Plate VI), but the fimbriæ at the smallest or proximal end of the spiculum, and the foliated extremity of the adjoining hamus, are still separated from each other; and this progressive development may be observed in all its stages, until the connexion of the parts is completed, and the fully developed form represented in Fig. 147, Plate VI, is produced. The same progressive development of this form of spiculum may be traced in those of *Hymeniacidon lingua*, Bowerbank, from the Hebrides.

In the performance of their natural office in the sponge, we find the same laws of attachment and projection obtain that I have described in treating of the bihamate spicula. In the equi-anchorate forms, where the terminal palms or teeth are equally developed, the shaft is attached by the middle of the external curve; but in the inequi-anchorate forms, where one palm is developed to a very much greater extent than the other, we find the smaller one is attached to the membrane, and the larger is projected at about an angle of 45 degrees. Generally speaking, the anchorate spicula, like the bihamate ones, are irregularly dispersed over the surface of the membranes, but occasionally, as in *Hymeniacidon lingua*, they are developed in circles or rosette-formed groups.

In many cases these groups contain so large a number of spicula as to render any attempt to count them ineffectual, and in some instances so many are developed that the group assumes the form of a ball rather than that of a

rosette. Fig. 297, Plate XVIII, represents a rosette-shaped group containing about the usual number of spicula.

Besides the rosette-shaped groups in *Hymeniacidon lingua*, there are a considerable number of these spicula dispersed over the surfaces of the membranes, but the attachment of these spicula is more frequently at the middle of the shaft than at the smaller end of the spiculum, their normal point of attachment. In the single and separate mode of disposition they are performing the office of equi-anchorate spicula, and the mode of their attachment is varied accordingly; but under these conditions they are rarely ever so fully developed, nor do they attain the same size as those which form the radiating groups. Notwithstanding the numerous groups and dispersed spicula of the inequi-anchorate form, this sponge is also abundantly furnished with bihamate spicula of various forms, but they are never congregated like the anchorate ones.

The same radiating mode of arrangement occurs in a parasitical Australian sponge from Freemantle, but the form of the terminations of the spicula is very different from those of *Hymeniacidon lingua*. The distal termination of each of the inequi-anchorate spicula is shortened in length, but expanded laterally to a considerable extent, and its terminal edge is furnished with three thin pointed teeth. The distal end has two small expanded and raised wings, projected in the direction of the inner curve of the spiculum, and so disposed as to cause it to resemble very closely an engineer's spanner for bringing up to their bearings projecting square-headed screws. Thus, although the forms of the termination of the two varieties of spicula vary to a considerable extent, the principles of their structure and purposes are in perfect unison. Fig. 135, Plate VI, represents a single spiculum highly magnified to display the peculiarity of their structure.

As may be imagined, from their office and situation in a thin stratum of a gelatinoid sarcode, they are at all times small, and in many cases so minute as to require a microscopic power of at least 600 linear to render their structure

distinctly visible. They occur in all parts of the sarcodous surfaces of the interior of the sponge, and are frequently found in greater profusion than usual on the inner or sarcodous surface of the dermal membrane; but I do not recollect an instance of their occurrence on the outer surface of that organ, while on the sarcodous or interstitial membranes they are frequently to be observed in about equal proportions on both sides of the same membrane.

It will not be necessary to describe or figure the whole of these variable forms of spicula. I have therefore selected those only that may be considered more especially as type forms.

Spicula of the Sarcode.

As the tension spicula of the membranes are destined to strengthen and support those tissues, so the numerous and beautiful tribe of stellate spicula appear to be devoted to connect and give substance, and in some instances to defend the gelatinoid sarcode, which so abundantly covers the whole of the interior membranous structures of the sponges in which they occur. It is difficult at first sight to determine the difference in the office of this class of spicula, and those of the internal retentive ones; and it is probable that in some cases, when it so happens that the radii of the stellate forms rest on, and become cemented to the membranous structures, they may perform, to a certain extent, the same function, that of assisting to connect the membranes and sarcodous structures more firmly together. But generally speaking this is not the case, and especially with the smaller forms of these organs; for in comparatively thick layers of sarcode we find them in all parts, and manifestly unconnected with the membranes beneath; and in sponges which have undergone such an amount of decomposition as to leave the membranous structures entirely, or very nearly, free from sarcode, while we see the retentive forms remaining firmly attached to the membranes, we rarely find the stellate ones, excepting when entangled among the surrounding spicula of the

skeleton. We may, therefore, reasonably conclude, that their normal function is that of increasing the strength and substance of the sarcodous structure of the sponge.

In the performance of this office of strengthening and supporting the sarcode, we find a singular class of spicula, consisting of from three to six rays, emanating from a common centre, and always disposed at right angles to each other. Between the extreme forms of development of these and the simple stellate spicula, there is a very great amount of structural difference; but on a more intimate acquaintance with the intermediate forms, we find them passing into each other so gradually as finally to connect the whole into one group.

It is not in the Spongiadæ only that these singular and beautiful organs are found. In the soft parts of the extensive family of the Gorgoniadæ they are in vast abundance, and in every variety of form, from an elongate tubercular spiculum to the elongo-stellate forms of the Spongiadæ, and the prevalence of the bluntly terminated radii is strongly indicative of their non-defensive character. But this latter quality does not obtain in other cases, either as regards the higher tribes of animals or the Spongiadæ. Thus we find in numerous species of compound tunicated animals their fleshy substance is crowded with sphero-granulate spicula, very closely resembling in form those of the sphero and subsphero-stellate shapes so abundant in *Tethea Ingalli* and *T. robusta* (Figs. 164 and 165, Plate VI). In both these cases the acute termination and the peculiarities of their respective situations are indicative of their subserving the office of defensive, as well as that of consolidating spicula.

Simple Stellate Spicula.

Stellate spicula are composed of few or many radii emanating from a centre in all directions. Their simplest form is when the bases of the radii all proceed from a common central point (Fig. 158, Plate VI), in which case they should be designated simply, stellate spicula; but

when the radii spring separately and distinctly from a common central spherical or oval base, they should be designated sphero-stellate spicula (Figs. 162, 164, 165, 166, 167, Plate VI). In both these classes of spicula there is a very considerable difference in their size and form, in the various species of sponges in which they occur.

Compound Stellate Spicula.

The curious and beautiful forms of this series of spicula all belong to the class of sponges that have a skeleton composed of siliceous fibre, and they are principally from tropical climates. The central basal structure from which the radii are projected, in every case with which I am acquainted, is a rectangulated hexradiate spiculum, from the apices of which a variety of beautiful terminations are projected, which vary in form exceedingly in different species of sponges. In the class of sponges to which I have alluded there are also numerous rectangulated spicula, varying in the number of radii from three to six, the apices of the radii being either acutely terminated or more or less elevated, and these forms vary very much in size. They are unconnected with the skeleton, and evidently belong to the Sarcodous system of the sponge. They are very much larger than the hexradiate centres of the compound stellate spicula, but as they are evidently the normal forms of that tribe, I shall describe the general characters of these large, simple, hexradiate forms before those of the more complicated stellate ones.

Attenuated rectangulated hexradiate (Fig. 174, Plate VII.)—The first state in which we find them is in that of an inequi-acerate spiculum (Fig. 175), in which condition they are in fact the two axial radii of the hexradiate form which they ultimately attain when in their fullest state of development. In the next stage we find a bud-like projection issuing from the side of the thickest portion of the inequi-acerate spiculum (Fig. 176), which is ultimately developed in the form of a rectangulated triradiate spiculum, as in Fig. 179. Or two buds

are simultaneously projected, as in Figs. 177 and 178, and the result is a regular rectangulated quadriradiate form, as in Fig. 181. Or if the second ray be at a right angle to the one first projected, the result is an irregular quadriradiate figure, as represented by Fig. 180. In like manner the irregular pentradiate form arises from the absence of one of the four secondary rays, as in Fig. 182; or it sometimes occurs that the apical portion of the inequi-acerate axial spiculum is deficient, and the result is, as represented by Fig. 183, a regular pentradiate form. If the whole of the radii are equally produced, the result is then the regular attenuated rectangulated hexradiate spiculum, (Fig. 174.)

Sometimes, but rarely, we find a single ray more or less spinous at its distal end; in this case it is probable that it was attached by that point to the membranous structure, or to some part of the keratode of the skeleton.

The whole of these interesting spicula were obtained from Mr. Cuming's specimen of *Euplectella aspergillum*, Owen. They are abundant in that sponge, frequently filling up the interstices of the network of the siliceous skeleton, or otherwise entangled in the tissues. In Dr. A. Farre's specimen of *Euplectella cucumer*, Owen, they are equally abundant, and are not to be distinguished from those in Mr. Cuming's specimen. They are, like the great external prehensile spicula, and the fibre of the skeleton, composed of numerous concentric layers of silex, which readily separate from each other by decomposition.

I cannot say with absolute certainty that this tribe of spicula belong really to the sarcode, as I have never seen specimens of either of the species I have named, in which they occur in profusion, in such a state of preservation as to allow of their position being positively determined; but as in another specimen of sponge with a siliceous skeleton like that of *Dactylocalyx pumicea*, Stutchbury, the sarcode is preserved in excellent condition, and occurs in such abundance, filling all the interstices of the skeleton

of the sponge, and affording ample space for the imbedment of such spicula in its substance, I am, therefore, induced to think it probable that a similar abundance of sarcode may exist in *Dactylocalyx* and other similarly constituted sponges, and that hereafter even the largest of this tribe of spicula will be found completely imbedded in the sarcode.

Slender attenuated rectangulated hexradiate (Fig. 184, Plate VII).—Beside the large and stout attenuato-hexradiate spicula in *Euplectella aspergillum,* there are comparatively small and very slender ones, many of which are nearly of the same proportions as the larger ones; but generally speaking the axial radii are more elongated, and in some cases the basal end is extended to four or six times the length of the apical portion.

These spicula do not present the same irregularity in their development that we observe in the stout ones, and it is a rare occurrence to find one without the full number of rays. They are exceedingly numerous in the sponge, and they occur in closely packed fasciculi, the axes of the spicula nearly touching each other. Amidst these fasciculi we find the large stout forms imbedded, the whole of them apparently having been completely enveloped by the sarcode of the sponge.

Cylindro-rectangulated hexradiate: apically spined (Fig. 185, Plate VII).—This form is very abundant in an undescribed species of *Alcyoncellum* in the Museum of the Jardin des Plantes, Paris. The figure represents the upper portion of the spiculum only, the lower portion of the axial shaft being exceedingly elongated. When examined with a power of 400 linear, the apices of the radii are seen to be abundantly, but minutely spined. The axial shaft of this spiculum, without any of the lateral radii developed, is also abundant; it is exceedingly long, and at the proper distance below the apex we often observe a gradual enlargement of the diameter, as represented in Fig. 187, and the rudimentary canals for the lateral radii are frequently apparent.

This form of spiculum is also very abundant in *Dac-*

tylocalyx pumicea, Stutchbury, *Iphiteon* of the French Museum. In general character they are very similar to those of the *Alcyoncellum* described above, with the addition of the apices of the radii being more or less elevated.

All the simple rectangulated hexradiate forms of spicula hitherto described are large compared with the rectangulated hexradiate spicula which form the central bases of the compound stellate forms, and excepting the disparity in size, the transition from the last form described, to the complicated and beautiful compound stellate ones, is easy and natural; the apices of the hexradiate form becoming the bases of the numerous radii of the stellate ones. This transition from the simple to the compound forms is admirably illustrated in a bifurcated spiculum that occurs in the new species of *Alcyoncellum* in the Museum of the Jardin des Plantes. This form I have designated bifurcated rectangulated hexradiate stellate, represented by Fig. 188, Plate VIII. The next stage of development is when we find each ray of the simple rectangulated hexradiate spiculum terminated by either three, four, or eight symmetrically disposed spicula, as represented by Figs. 189, 190, 191, and 192, Plate VIII, and their terminal secondary radii are either acute or spinulate.

A still further amount of development is apparent in the beautiful *Floricomo hexradiate* form represented by Figs. 193 and 194, Plate VIII.

The central radii consist of six rectangulated primary rays of equal length, with slightly expanded terminations, from each of which there issues seven or more petaloid secondary spicula, the whole forming one of the most beautiful simulations of a flower imaginable.

Each petaloid spiculum is slender at its proximal termination, and continues to be so until near its distal end, where it expands laterally, and presents a nearly semicircular concavo-convex termination, with a beautiful dentate margin, the number of the dents being usually seven. Each of the petaloid spicula curves gently outward from its base, the flowing line returning towards the central axis of the flower at about half of its height from

the base, and then it again curves outward, until the apical expansion is at right angles to the floral axis; so that the whole resolves itself into a form like that of the flower of a Jasmin. The beautiful terminal petaloid expansions, with their regularly disposed marginal dents, renders the illusion complete; the united basal curves looking as if they had been produced by the swelling ovarium of a flower.

I have obtained a considerable number of these elegant spicula from my friend Mr. Cuming's beautiful specimen of *Euplectella aspergillum*, Owen, which, with his accustomed liberality, he placed at my disposal for examination. They are found also in Dr. A. Farre's specimen of *Euplectella cucumer*, Owen, agreeing in every respect with those from Mr. Cuming's sponge.

Generally speaking, the slender rectangulated hexradiate spicula occur singly, but I have sometimes found them grouped together; in this case their axes were coincident and their radii in the same plane, or very nearly so, but not always agreeing in their direction; such a framework would form a very fitting support to a large mass of sarcodous tissue partially separated from the framework of the skeleton and occupying a portion of a large interstitial space.

In the large open areas of the skeleton of *Euplectella aspergillum*, Owen, the hexradiate forms, ranging from Figs. 174—183, Plate VII, are exceedingly abundant, and a considerable number of them are not developed to the extent of the full number of their radii. This may probably arise from the development of the radii being stimulated by the necessities of the mass of sarcodous tissues in which they are imbedded, and consequently where no necessity for their presence exists they would not be put forth. In the trifurcate and quadrifurcate hexradiate forms, if we may judge from the termination of their radii, they, like the simple stellate forms, are either purely consolidating, or they combine with that office that of defensive spicula also, as far as regards the sarcodous substance in which they are imbedded.

We can scarcely imagine any defensive properties in the

slender and complicated but elegant forms of the floricomo-stellate spicula, and it is probable that their office is purely that of assisting in the consolidation of the sarcodous substance.

The whole of these beautiful stellate forms of spicula are siliceous, while their homologues in the Gorgoniadæ and the compound tunicata are calcareous; and it is somewhat remarkable that hitherto none of these forms have been found in the calcareous species of sponges.

Spicula of the Ovaria and Gemmules.

We find the same laws in force regarding the spicula in the structure of the minute bodies which have been designated gemmules by previous writers on the Spongiadæ, that obtain in the sponges themselves. In some they serve the purposes of internal skeleton and defensive spicula as well. In others they combine the offices of tension aud defensive organs, and frequently they are very different in form from those of the parent sponge. They occur in various modes of disposition.

1. Those which have the spicula disposed at right angles to lines radiating from the centre of the ovarium to its surface.

2. Spicula disposed in lines radiating from the centre to the circumference of the ovarium.

3. Those having the spicula disposed in fasciculi in the substance of the gemmule from the centre to the circumference.

In the first mode of disposition they are sometimes of the same form as those of the skeleton, but considerably less both in length and diameter, to adapt them to the office they have to perform. In other cases they differ materially in both size and form from those of the surrounding skeleton; but in every case with which I am acquainted, their long axes are parallel to the outer surface of the case of the ovarium, or to the surface of the ovarium itself.

In the second mode of disposition they are immersed in

the comparatively thick crust of the ovarium, their long axes being always at right angles to lines radiating from its centre to its circumference. Their forms become widely different from those of the skeleton spicula, and especially adapted to their peculiar office; and their terminations frequently expand into broad plates, as in *Spongilla fluviatilis*, Johnston. Their forms vary considerably in shape and structure in different species. In the ovaries of some sponges, one of these modes of the disposition of their spicula only can be observed.

In the third mode of arrangement, where the spicula abound in every part of the gemmule, as in *Tethea cranium*, Johnston, they are various in form, but resemble to a considerable extent those of the skeleton, with an intermixture of forms peculiar to the gemmule.

In *Spongilla Carteri*, Bowerbank, and *S. fluviatilis*, Johnston, our commonest British species, belonging to the first group, the external series of spicula of the ovaria are of the same form as those of the skeleton, but frequently somewhat shorter. They are disposed irregularly over the surface of the ovarium, and firmly cemented to it by the middle of the shaft, while each of their apices are projected in tangental lines. Thus their shafts perform the office of tension spicula, while their terminations become efficient weapons of defence. Fig. 201, Plate IX, represents the spiculum of the ovary of *S. Carteri*.

In other cases in this group we find these spicula differing from those of the skeleton of the parent sponge; thus the one represented by Fig. 203, Plate IX, from the surface of *Spongilla lacustris*, Johnston, is curved so as to accommodate it to the rotundity of the ovary (Fig. 320, Plate XXII), and we do not find its apices projecting as in those of *S. fluviatilis*, but instead of the projecting apices, the whole spiculum is covered with minute spines, assimilating it in character with the general structure of those spicula which combine the office of tension and defensive spicula, but differing considerably in their proportion from the tension spicula of the same sponge, *S. lacustris*, represented by Fig. 90, Plate IV, the one

being evidently destined to sustain and protect extended membranes, while the other is especially adapted for a small curved surface by its form and small size; each of the figures being drawn with the same power, 660 linear.

On the surface of the ovarium of *Spongilla cinerea*, Carter, we find this description of spiculum still more decidedly produced. It is of a cylindrical form and entirely spined, and has just the amount of curvature that is in unison with the surface on which it reposes. The spines on the middle of the shaft are cylindrical, and terminated bluntly so as to strengthen its hold on its imbedment. Those of its apices, on the contrary, are acutely conical and recurved, and are strongly produced so as to form very efficient weapons of defence. This spiculum is represented by Fig. 207, Plate IX.

The birotulate and boletiform spicula of the second group appear to be more purely structural, as regards the skeleton of the ovarium. The rotulæ are very closely packed at both the external and internal surfaces of that body, and the crenulation or dentation of each rotula is as well produced on the internal as on the external ones, and it appears to be very influential in maintaining each spiculum in its proper position. In the natural condition of the ovaria these spicula are entirely imbedded in its walls, and other spicula of a truly defensive nature are superimposed for its protection. The large spine in the shafts of the birotulate spiculum from *Spongilla plumosa*, Carter (Fig. 208, Plate IX), are also apparently subservient to strengthening and maintaining the spiculum in its proper situation, although they are acutely terminated, as defensive spines usually are; but in the same relative position on the birotulate spicula of *Spongilla Meyeni*, Carter, we find the spines short, stout, and cylindrical, spreading or budding at their apices, and evidently more fitted for assisting to retain the spiculum in its proper place than for defensive purposes. This spiculum is represented by Fig. 219, Plate IX.

There is an apparent analogy between the expansions of

the rotulæ and those of the foliato-peltate spicula, but they do not appear, like the latter, to be derived from the ternate forms. The radiation of the canaliculi, as represented by Fig. 222, Plate IX, are not derived from three primary rays, but each appears to emanate from a central cavity at the end of the shaft; and their number, 22, at their proximal termination, is not reconcilable with any regular number of bifurcations arising from three primary rays, however short we may imagine them to be.

The progressive decline of the inner rotula in the inequibirotulate spiculum of *Spongilla paulula*, Bowerbank (Fig. 221, Plate IX), and its all but total extinction in *Spongilla reticulata*, and *Spongilla recurvata*, Bowerbank (Figs. 223 and 224), until the distal rotula merges in the scutulate form, with an acute external umbo in place of an internal shaft as in *Spongilla Brownii*, Bowerbank, Figs. 226 and 227, exhibits a very interesting series of gradations of development in the same description of organ.

The whole of this beautiful group of spicula occur in the thick coriaceous proper coat of the ovaria of the Spongillidæ. Sometimes we have but one form thus located, as in *Spongilla fluviatilis*, Johnston, where we find them very close together in the case of the ovarium, as in Fig. 318, Plate XXII, the outer rotula supporting the external membrane, and the inner one performing the same office for the internal one, as represented by Fig. 319, Plate XXII. At other times we find two distinct forms in the coat of the ovarium, as in *Spongilla recurvata*, Bowerbank, from the River Amazon; the inner one being slender boletiform (Fig. 224, Plate IX), and the outer one multihamate birotulate (Fig. 220, Plate IX). In every case these spicula are so completely immersed in the thick coriaceous coat of the ovarium, that they are perfectly invisible under ordinary circumstances; and it is only after the ovary has been boiled in nitric acid for a very short period, that it is rendered sufficiently transparent to allow of the spicula being seen *in situ*.

The progressive development of these forms of spicula is very beautifully exhibited in the spicula from the ovaria of *Spongilla plumosa*, Carter. We first observe them, with a

linear power of 660, in the shape of slender, smooth, cylindrical spicula, with a slight enlargement at each termination, and without the slightest indication of spines on the shaft; and in this condition the central cavity is large, occupying about one third of its diameter (Fig. 210, Plate IX). In the second stage, the only alteration in its form is an enlargement of the terminations, the edges assuming an angular shape, and a few slender spines are observable (Fig. 211). In the third stage of development the terminations assume the form of distinct circular plates or incipient rotulæ, the margins of which are slightly crenate; the shaft exhibits numerous long slender spines, and the central cavity now does not occupy more than one fifth of the diameter of the spiculum (Fig. 212). From this form specimens in every stage of development may be readily traced, until the strongly spinous margin, the prominent convexity of the rotulæ, and the robust shaft with its long conical spines, indicate the completely adult condition of the spiculum, and in this state the central cavity can very rarely be seen (Fig. 208).

The growth of these spicula in their early stages is probably very rapid, as the number of those in the first and second stages is remarkably small as compared with those in the third and subsequent stages.

In the inequi-birotulate spicula of *Spongilla paulula*, Bowerbank, we find a number of radial canals passing from each end of the central cavity of the shaft to the extreme circumference of the rotulæ; and it is therefore probable that this expanded part of the spiculum is similar in character to that of the foliato-peltate spiculum which I have described (Terminology, 102) in treating of the spicula of the membranes; and that they are, in fact, originally composed of a series of terminal radial spicula expanding and coalescing laterally, and thus forming one plane circular surface in place of numerous separate radii (Fig. 222).

The spicula of the third group, those having the spicula disposed in fasciculi in the substance of the gemmule, differ less in character from those of the parent sponge than

those of either of the preceding groups. They are in reality but modifications of the external defensive spicula of the parent sponges.

The inequi-fusiformi-acerate one (in the Gemmule of Tethea) differs from the fusiformi-acerate one of the skeleton in no other respect than in the greater proportionate attenuation towards its distal termination, which gives it a degree of flexibility that allows of its bending freely under the pressure of any comparatively large body; and I have seen them, when two gemmules have been pressed closely together, bent to the extent of semicircles without breaking. In the young gemmules these spicula are usually projected much beyond the other forms of defensive spicula that accompany them.

In like manner the small attenuato-porrecto-ternate form in the same gemmule is a modification of the similarly formed external defensive spicula of the parent sponge. In the adult gemmule the apices of these spicula rarely project beyond the dermal membrane, and it is only on pressure from without that they would be brought into effective use. The amount of the angle of their radiation at the apex of the spiculum is therefore greatly increased beyond those of the external defensive ones of like form in the parent sponge, so as to accommodate their apices to the curve of the surface of the gemmule, and to render each point equally effective; and as they are not projected beyond the dermal surface, as in the sponge, their shafts are shortened proportionally.

The unihamate, bihamate, and recurvo-ternate forms of the same gemmules are also modified forms of the recurvo-ternate external defensive spicula of the parent sponges, *Tethea cranium* and *similima*.

KERATODE

Is the substance of which the horny elastic fibres of the skeleton of the officinal sponges of commerce are composed. It has, correctly speaking, no relationship either chemically

or structurally with horn, and Dr. Grant has judiciously rejected the term "horny fibre" as applied to the sponges of commerce, and has substituted that of keratose by way of distinction; and in accordance with that term I propose to designate the substance generally as keratode, whether it occurs in the elastic fibrous skeleton of true *Spongia*, which are composed almost entirely of this substance, or of those of the Halichondraceous tribe of Spongiadæ, where it is subordinate to the spicula in the construction of the skeleton, and appears more especially in the form of an elastic cementing medium. In a dried state it is often extremely rigid and incompressible, but in its natural condition it is more or less soft, and always flexible and very elastic. It varies in colour from a very light shade to an extremely deep tint of amber, and it is always more or less transparent. In its fully developed condition, in the form of fibre, it appears always to be deposited in concentric layers; but in the mode of the development of these layers there are some interesting variations from the normal course of production. As we find in *Aranea diadema*, the common Garden Spider, that the creature has the power of modifying the deposit of the substance of its web so that the radiating fibres dry rapidly while the concentric ones remain viscid for a considerable period, so we find in the production of the young fibres of the skeletons of the Spongiadæ in some species, as in those of commerce, there is no adherent power at the apex of the young fibre, excepting with parts of its own substance; while in *Dysidea*, and in some other genera, the apex of the newly-produced fibre is remarkably viscid, adhering with great tenacity to any small extraneous granules that it may happen to touch in the course of its extension (Fig. 272, Plate XIV); but this adhesive character appears to be confined to the earliest stages of its production only, as exhibited at the apices of the newly-produced fibres, the external surface immediately below the apex exhibiting no subsequent adhesive property.

Lehman, in his 'Physiological Chemistry,' Cavendish Society's edition, vol. i, p. 401, states that *Spongia officinalis*

of commerce consists of 20 atoms of fibroin, 1 atom of iodine, and 5 atoms of phosphorus; and in treating of the physiological relations of fibroin as regards sponges, he observes, "Its chemical constitution affords one of the arguments why the *Spongia* should be classed among animals and not among plants, since in the vegetable kingdom we nowhere meet with a substance in the slightest degree resembling fibroin."

From the general physiological characters of the skeletons of the Sertularian and other Zoophytes, I had long suspected that their component parts were identical, or very nearly so, with those of the skeletons of the Spongiadæ, and I therefore applied to my friend, Mr. George Bowdler Buckton, to assist me in determining this point, and he very kindly undertook to make comparative qualitative analyses with two species of Zoophytes, *Sertularia operculata* and *Flustra foliacea*, with the fibres of *Spongia officinalis* and of raw silk, and I cannot do better than to quote entire the report of the results of his examination:

"I have examined the Zoophytes you sent me, and have compared their deportment under chemical agency, with that shown by white silk and the fibre of ordinary sponge.

"All the specimens were treated in a similar manner, being purified from foreign matter, as far as possible, by boiling for two hours in water, and subsequently for the same period in strong acetic acid. With the exception of *Flustra*, the substances exhibited by this treatment little change in their outward appearance. Carbonate of lime enters so largely into the composition of *Flustra*, that its disintegration by acids ought to cause no surprise.

"From the results of the first seven experiments,* I conclude that all these bodies contain the same, or a very similar animal principle, which I suppose to be identical with Mulder's fibroin. The varying colours of the precipitates from tannic acid and ammonia, I think is probably

* For a table of the results of the analysis of Mr. Buckton, see 'Philosophical Transactions' for 1863, page 740.

due to the traces of sesquioxide of iron present in the fibres, and the difference in shade is simply caused by the greater or less preponderance of that metal.

"Although I have not been able to obtain fibroin in a state of chemical purity, I would state that, to my knowledge, there is no vegetable principle which behaves itself towards reagents in a manner similar to that shown by the substance of silk, sponge, &c.

"Mulder and Crookewit's analyses show silk and sponge scarcely to differ in composition.

	Fibroin from Silk.		*Fibroin from Sponges.*	
Carbon	48·5	Carbon	46·5 to	48·5
Hydrogen	6·5	Hydrogen	6·3	6·3
Nitrogen	17·3	Nitrogen	16·1	16·1
Oxygen, Sulphur, &c. &c.	27·7	Oxygen, Sulphur, Phosphorus, Iodine	31·1	29·1
	100·0		100·0	100·0

Schlossberger has recently expressed his doubts of the identity of composition of these bodies, from the circumstance that silk is readily soluble in strong ammonia, saturated with oxide of copper, whilst sponge is scarcely, or not at all, affected by long maceration. My own experiments prove the same fact, yet it is not impossible that the minute quantities of iodine, phosphorus, and sulphur present in sponge may modify the solubility of the fibre.

"Under the supposition that a resinous gum might act as a protection, portions of sponge were boiled in benzol, ether, and alcohol, but these solvents did not modify the characters in any noticeable degree.

"I consider, however, that this difference between sponge and silk in no wise affects the question of the former substance being a product of the animal kingdom, which the other experiments, I think, satisfactorily prove."

In considering the results of these analyses with a view

to proving the animal nature of the Spongiadæ, the evidence afforded by the coincidence of its structural character and its chemical constituents with those of *Sertularia operculata*, are still more conclusive than that derived from the chemical constituents of silk; and, in truth, the action of the chemical agents on the zoophyte and the sponge, as might naturally be expected, are almost in perfect accordance.

MEMBRANOUS TISSUES.

These structures may be divided into two classes:

1st. Simple membranous tissue.

2nd. Compound membranous tissue.

The first is a simple, apparently unorganized, thin, pellucid tissue. It is evidently not composed of an extension of keratode, as it is rapidly decomposed after the death of the animal. It is found in abundance filling up the areas of the network of the skeleton in a great variety of sponges, and it appears to be capable of secreting sarcode on both its surfaces when thus situated; on the dermal membranes the sarcode is found on the internal surface only.

Compound membranous tissues.—These structures consist of simple membranous tissue combined more or less with primitive fibrous tissue. Their most simple forms exist in the membranes lining the interstitial cavities of the sponge, and in the dermal membranes.

It is difficult in some cases to discriminate between this class of tissues and simple membranes, unless it be by the aid of their functional characters, as the compound tissues are frequently quite as pellucid, although not so thin, as the simple ones.

In dermal membrane, and the membranous linings of the internal cavities of the sponge, they are thin and very translucent; but by a careful examination with high microscopic powers and transmitted light, with the aid of polarization, we frequently detect the elastic primary

fibrous tissues incorporated with the structure. In the contractile membranes forming the oscular diaphragms in *Grantia*, and in those at the base of the intermarginal cavities in *Geodia* and *Pachymatisma*, they attain a greater degree of thickness, and especially in the two latter genera of sponges. In *Alcyoncellum*, Quoy et Gaimard, the organization of their tissue is still more complex, and we there find them constructed of repeated layers of membranous structure, abounding in primitive fibrous tissue disposed in parallel lines in each layer, the fibres disposed so closely together as to completely cover the membrane beneath, and the direction of the fibres being at various angles to the axis of the great cloacal appendages of the sponge, so as most effectually to aid in the contraction or expansion of that organ. They are so closely packed together and so intermingled, that I could not ascertain their length but from the gradual attenuation of some of their terminations; they would seem not to be continuous for any considerable distance. On some of the layers of this compound membrane the fibres were disposed in an even and continuous stratum, while in others they were gathered into broad, flat, parallel fasciculi. When the compound structure consists of several layers of fibro-membranous structure, the disposition of the fibres on the different layers are not coincident. In some cases they cross each other at right angles, while in others the angle does not exceed 45 degrees. The latter mode of arrangement appears to prevail in the membranes connecting the great longitudinal fasciculi of spicula, forming to a great extent the skeleton of the cloacal appendages of the sponge; while the arrangement at right angles appears also in the tissues immediately surrounding the great skeleton fasciculi.

This fibro-membranous tissue abounds in the dermal and interstitial structures of the sponges of commerce, but the greatest development of this structure is exhibited in the genus *Stematumenia*.

Fig. 255, Plate XII, represents a small portion of the lining membrane of one of the great excurrent canals of

the common honeycomb sponge of commerce, in the condition in which it came from the sea. The primitive fibrous tissue is seen arranged in a single layer in parallel lines at right angles to the long axis of the canal, but partially obscured by the stratum of sarcode on the membrane.

Fig. 256, Plate XII, represents a small portion of the dermal membrane of a *Stematumenia*, in which the primitive fibres are seen wandering in every direction over the surface of the membrane.

Figs. 257 and 258 in the same plate represent portions of a stouter and a more compound membranous structure, from the walls of one of the great cloacal projections from the surface of *Alcyoncellum robusta*, Bowerbank. In this case the membrane is strengthened by two or more layers of primitive fibrous structure, the parallel fibres of each crossing the others at various angles.

FIBROUS STRUCTURES.

There are two well-characterised classes of fibrous structure:

1st. Primitive fibrous tissue.

2nd. The fibres of the skeleton.

1. *Primitive Fibrous Tissue.*

The first of these tissues is exceedingly minute. The fibres are cylindrical in form, and are usually of considerable length; but where they are fully developed, they occur in such numbers, and in such a matted condition, that I have been unable to separate an unbroken one from the mass. They continue through the whole of their length as nearly as possible of the same diameter, and there rarely appears to be any attenuation towards their terminations, which are usually obtuse. They are evidently very elastic and contractile. When partially separated from their attachments to the membranes, the free ends seldom remain

straight, and most frequently they curl considerably in different directions. They appear to be perfectly solid; I could not by the aid of polarization discover the slightest indication of a central cavity. They vary in diameter in different species of sponge, and frequently so even in the same individual. In a species of *Stematumenia* from the Mediterranean, I measured an average-sized fibre which was $\frac{1}{4166}$ inch in diameter, while a smaller one, closely adjoining, measured $\frac{1}{9375}$ inch. In this genus these fibres are more fully developed and larger in size than in any other sponges with which I am acquainted. In the sponges of commerce, in the membranes of which they are exceedingly numerous, they are much more slender. In one of the excurrent canals of the common honeycomb sponge, one of the largest measured $\frac{1}{10,000}$ inch in diameter, and one of the smallest $\frac{1}{17,647}$ inch. In the dermal membrane of the best Turkey sponge they were still less, not exceeding $\frac{1}{18,000}$ inch.

This description of fibre is not an absolutely necessary constituent of a sponge, and in many of the Halichondraceous tribes it is exceedingly difficult to find even a single straggling fibre on the interstitial or dermal tissues, while in other genera, as in *Spongia, Stematumenia,* and *Alcyoncellum,* they form an important element in the structure of the compound membranous tissues, in which they are closely disposed in parallel lines, occasionally giving off branches, but never appearing to anastomose with each other like the larger fibres of the skeleton.

These fibro-membranous tissues were described by me in the 'Annals and Magazine of Natural History,' vol. xvi, page 406, plate xiv, figs. 1, 3, 4, and 5, in my description of the genus *Stematumenia.*

If a small portion of the dermal membrane of a young Stematumenia be carefully removed from the surface of the sponge, the primitive fibres will be seen projecting from the edges of the membrane in considerable numbers; and occasionally they may be seen to be furnished with a terminal bulb, the greatest diameter of which is about three times that of the fibre. The bulbs are variable in form;

sometimes they are largest at the base, or pear-shaped, at other times regularly oval, or nearly globular. By far the greater number of fibres exhibit no bulbs at their terminations; those which have them are always less in diameter than the general average of the fibres. Sometimes, but not very frequently, the bulb exhibits faint traces of a nucleus. On examining the dermal membrane by transmitted light and a linear power of 666, I found numerous globular cells collected in groups on various parts of its inner surface, many of them having a well-defined central nucleus; and among these cells I found the bulbs imbedded, with the fibres emanating from them, and in no respect differing in appearance from the non-fibrous cells around them (Fig. 259, *a*, *a*, Plate XII). On carefully observing a number of these bulbous fibres that had been removed from their positions on the membrane, I found that the part of the fibre nearest to the bulb was frequently flexuous, as if in a tender and immature condition, and in these cases the marginal line of the fibre was continued without the slightest break or interruption into and around the bulb, as represented in Fig. 260, *a*, Plate XII. At this period of the development the young fibre does not measure above half the diameter of a mature one, and there is no indication of an ultimate separation from the bulb; but when the fibre has attained nearly the full size the separation is then distinctly indicated; the basal end of the fibre immersed in the bulb becomes hemispherical, and a constriction appears at the junction of the fibre with the exhausted cell. Sometimes, when thus affording indications of their ultimate separation, the cell still retains its rotundity, but all indication of its nucleus has disappeared, and it is perfectly transparent, as represented in Fig. 260, *b*, Plate XII, while in other cases it is visible only as a collapsed and shrivelled vesicle adherent to the hemispherical termination of the fibre, as represented in Fig. 260, *c*, Plate XII. I could not find the slightest indication of bulbs amid the matted mass of fibres lying on the inner surface of the membrane, and it was only at the torn edges of the pieces of membrane under examination, or

among the groups of cells, that the bulbs in connexion with the fibres were to be discovered.

This form of fibrous tissue is not essentially a sponge structure; it enters largely into the composition of the membrana putaminis, and the shell of the egg of the domestic fowl, and I have also found it in the foliated portion of a coral, *Pavonia lactuca,* when deprived of its earthy matter by dilute hydrochloric acid; and it occurs also in the membranes of some species of Ascidians. Prof. Bowman, in his treatise on mucous membrane, in the 'Cyclopædia of Anatomy and Physiology,' in his description of the white fibrous element of areolar tissue, says, "Beside these bands, commonly called fasciculi, there are some finer filaments of the utmost tenuity, which seem to take an uncertain course among the rest." These filaments, it is very probable, are the homologues of the primitive fibrous tissue which I have thus described.

2. *Keratose Fibrous Tissue.*

General character of the keratose fibres of the horny skeleton.—The essential character of the fibres of the horny skeleton is, that their normal form is always that of a cylinder, while the network of the skeletons of the Halichondroid sponges, which approach nearest in structure to that of spiculated keratose fibre, is always more or less irregular in shape; and in the fully developed state generally compressed to a very considerable extent; but a careful examination of the youngest portions of the two forms of skeleton-tissue will always render the difference in the two structures apparent. In the spiculated keratose fibre the keratode is always the predominant element, and the spicula the subordinate one; while in the skeletons of the Halichondroid sponges the spicula always predominate, and the keratode is merely the secondary or surrounding medium. In the former structure, in the extension of the terminations of the skeleton, the keratode is the leading element, while in the latter the spicula take the lead.

The fibre is formed of a succession of concentric layers,

its increase in diameter being apparently effected at the external surface. Its longitudinal extension appears to be caused by a progressive elongation of their terminations, and new fibres are frequently to be seen pullulating from the sides of the mature ones. In the dried state it is often extremely rigid and incompressible, but in its natural condition, notwithstanding there is frequently an internal axis of extraneous matter or of spicula, it is often remarkably soft and flexible. The spicula, although immersed in the fibre, evidently possess a considerable amount of mobility within the surrounding medium.

The colour of the fibres is always amber-yellow, varying in different species from a very light to a deep yellow-brown tint, and it is always semi-transparent. In the living state, when the fibres happen to touch each other, whether by their terminations or laterally, they appear at all times to unite.

The keratose skeleton-fibres vary in their organization to a very considerable extent, but the whole of them may be comprised in the following nine typical forms:

1. Solid simple keratose fibre.
2. Spiculated keratose fibre.
3. Hetro-spiculated keratose fibre.
4. Multi-spiculated keratose fibre.
5. Inequi-spiculated keratose fibre.
6. Simple fistulose keratose fibre.
7. Compound fistulose keratose fibre.
8. Regular arenated keratose fibre.
9. Irregularly arenated keratose fibre.

1. *Solid Simple Keratose Fibre.*

The typical form of this description of fibre is that which forms the skeleton of the Turkey sponges of commerce, the structure of which I described in a paper read before the Microscopical Society of London, and published in vol. i, p. 42, of its 'Transactions.' The mature fibre is perfectly solid, and no vestige of a central cavity can be observed in any part of it, either when viewed by transmitted light or

in transverse sections of the fibre, by the aid of a Lieberkuhn. Occasionally, but very rarely, I have seen in young and immature fibres faint and irregular indications of there having been a very small central cavity in perhaps the earliest period of its development, but in the mature fibre I have never been able to trace such cavities (Fig. 261, Plate XIII).

This description of fibre is occasionally surrounded by a membranous sheath, on which is imbedded a beautiful system of hollow fibrils or vessels, which sometimes wind round the skeleton-fibre in a spiral direction; at others it assumes a longitudinal course, giving off short cæcoid branches; or it forms a complex and irregular network. In an Australian sponge in my possession, the latter mode is the only form in which it occurs. In some of these minute fibrils or vessels I observed numerous minute globules, which were rendered movable by a slight pressure on the glass under which they were exhibited. The mean diameter of these tubes or vessels was $\frac{1}{9346}$ inch. This tissue is of rare occurrence, and I have been unable to determine whether it is a specific character, or whether it is due to a peculiar condition of the sponge. Fig. 279, Plate XVI, represents a portion of fibre from the skeleton of one of the sponges of commerce. Fig. 280, Plate XVI, is from a rigid species of Australian sponge. This singular tissue is described more fully in a paper which I read before the Microscopical Society of London in 1841, and which is published in their 'Transactions,' vol. i, p. 32, plate iii.

2. *Spiculated Keratose Fibre.*

This structure is essentially a solid form of keratose fibre, no central cavity ever being visible in its axis. The normal form of the fibre is cylindrical, but it is occasionally more or less compressed, and always contains a thin central line or axis of spicula arranged in longitudinal series. The spicula are secreted within the fibre, and are nearly uniform in size, and always of the same shape in the same species

of sponge. In the production of the young fibres, the projection of the new keratode and the secretion of the new spicula appears to be simultaneous. In this class of structure the keratose fibre is the predominant element, and the spicula the subordinate one, and we accordingly frequently find the fibres destitute of spicula for short distances; but these occurrences are the exceptions, and not the rule of the structure. Fig. 262, Plate XIII, represents a portion of a longitudinal section of the skeleton of *Halichondria oculata*, Johnston (*Chalina*, Bowerbank).

The mode of the progressive development of this form of fibre is interesting. In a young specimen of *Chalina Montagui*, Bowerbank, I observed that when a new fibre was projected from the skeleton it usually contained a single spiculum, thinly covered by keratode at the apex, and more thickly so towards the basal end. Another spiculum followed the first, the terminations of each overlapping the other; and at the junction of the two the keratode was accumulated in the form of a plumber's joint, as represented in Fig. 263, Plate XIII, so as to give additional strength to the junction of the spicula, while the middle portion of the second spiculum remained very thinly covered by keratode. When the distal end of the new fibre has attained its proper length, or has become cemented to the side of another fibre, the remaining portion of the keratode is produced, and the fibre then assumes a regular cylindrical form.

3. *Hetro-spiculated Keratose Fibre.*

This form of fibre has a somewhat irregular axial series of spicula, with occasionally exter-axial ones disposed in accordance with the axial spicula, and others at intervals at right or nearly right angles to the axis of the fibre. The only sponge in which I have found this form of fibrous tissue is *Diplodemia vesicula*, Bowerbank, from deep water, Shetland. Fig. 273, Plate XIV, represents a portion of a skeleton-fibre.

4. *Multi-spiculated Keratose Fibre.*

This description of fibre is literally a cylindrical mass of spicula cemented together by keratode, and surrounded by a thin case of the same substance. The spicula are exceedingly numerous, and very closely packed in parallel lines in accordance with the axis of the fibre. They are nearly uniform in size, and always of the same shape in the same species of sponge. In this structure the spicula are the predominant element, and the keratode the subordinate one. Fig. 264, Plate XIII, represents a fibre from the skeleton of *Desmacidon ægagropila*, Bowerbank.

5. *Inequi-spiculated Keratose Fibre.*

This form of fibre is composed of an infinite number of spicula disposed in every possible direction, cemented together by keratode, and surrounded by a sheath of the same material. The spicula agree in form in all parts of the sponge, and are nearly of the same size. In these fibres the spicula are the predominant element, the keratode the secondary one. In the only sponge in which this form of structure has yet been found, *Raphyrus Griffithsii*, Bowerbank, the fibre is very unequal in size and much varied in its form, frequently becoming very much flattened and expanded. Fig. 265, Plate XIII, represents a longitudinal section of a small portion of a fibre from the skeleton, showing the irregular disposition of the spicula within it.

6. *Simple Fistulose Keratose Fibre.*

This form of fibre is usually very much larger and more rigid than the solid keratose fibre. It is cylindrical, and continuously fistular. The great central cavity of the fibre usually occupies about one third of its diameter. It is nearly uniform in its size, but occasionally it is dilated considerably for a short space, and then resumes its original

diameter. In the young state the cavity is as large, or nearly so, as in the adult fibres, while the enveloping keratode assumes the form of a thin, transparent, amber-coloured coat, which in the mature state becomes frequently twice or three times the thickness of the diameter of the central cavity.

This great fistular space is lined with a thin pellucid membrane, which, in specimens that have been dried, appears to have been thickly covered with minute semi-opaque granules. At the time of my first description of this form of fibre, published in the 'Annals and Magazine of Natural History,' vol. xvi, p. 403, I believed that in the natural condition of the fibres the central cavity was an open tube, but subsequent observations on specimens which have never been dried have led me to the conclusion that the whole of the central space is filled with a minutely granulated substance, which presents all the characteristics of sarcode.

There is no communication between the great central fistular canal and the interstitial cavities of the sponge, the projecting ends of the fibres of the skeleton being always hermetically sealed. Fig. 266, Plate XIII, represents a fibre from the specimen of *Spongia fistularis*, Lamarck, in the Museum at Edinburgh, given to me by Prof. Grant.

7. *Compound Fistulose Keratose Fibre.*

In its external characters this description of fibre is not, under ordinary circumstances, to be distinguished from the simple fistulose fibre, and it is only when submitted to a microscopical power of about 100 linear that its peculiar character can be detected. We then find that the fibre is not only furnished with a large continuous central cavity, but that it also has numerous minute cæcoid canals radiating from the central one at irregular distances, at nearly right angles to its axis. These secondary canals are very unequal in length, and very few of them reach to near the external surface of the fibre, and none of them appear to perforate it. Their direction is usually in a straight

line from the parent canal; a few assume a tortuous direction, and a still fewer number bifurcate or branch. Within the central tubes of the fibres there are frequently one or two minute simple tubular fibres; when more than one they do not unite, but they divide and traverse each a separate cavity, when they happen to reach one of the anastomosing points of the great skeleton-fibre. The structures are described more at length in the 'Annals and Magazine of Natural History,' vol. xvi, p. 405, under the head of "*Auliskia*," a new genus of sponges, founded principally on the compound fistulose structure of its skeleton-fibres. Fig. 268, Plate XIV, represents a portion of compound fistulose keratose fibre as seen with a linear power of 100. Fig. 267, Plate XIII, a portion of a similar fibre under a power of 300 linear.

8. *Regular Arenated Keratose Fibre.*

This description of fibre under ordinary circumstances has very much the appearance of simple fistulose fibre, but when examined by transmitted light with a linear power of about 100 we find in the centre of the fibre a series of grains of extraneous matter, occupying the place of the large continuous canals of the fistulous forms of fibre. The series of extraneous matters is not always continuous, and when an interruption takes place the fibre becomes solid, or faint traces only of a central cavity remains. The mode of the inclusion appears to be due to the extreme terminations of the young fibres being viscid, and thus seizing on any extraneous particles that happen to come in contact with them. The growing keratode quickly envelopes them, and, proceeding on its course of extension, seizes in like manner on other particles of sand or solid matter, and thus a continuous and regular chain of extraneous material is imbedded in the axis of the fibre, as represented by Fig. 269, Plate XIV. This description of fibre is found in a great variety of keratose sponges, and especially so among the coarse rigid skeletons of the Australian species. And among the flexible sponges, as represented by Fig. 269.

9. *Irregular Arenated Keratose Fibre.*

I have described this form of fibre in a paper descriptive of two species of *Dysidea*, read at the Microscopical Society of London, Nov. 24, 1841, and subsequently published in vol. i, p. 63, of their 'Transactions.'

The adult and fully produced fibre is frequently half a line or more in diameter. It is built up in all parts of its substance, of grains of extraneous matter, each one being separately enveloped in keratode. The adhesive power in the young progressing fibre not being confined to its apex only, its sides also seize upon the surrounding grains of solid matter, and the keratode speedily passing round and enveloping them, the whole fibre becomes a solid cylinder of irregularly imbedded molecules. There is a great variety of substances imbedded in these fibres, dependent, as a matter of course, on the amount of material surrounding them at the period of their development. The skeleton of *Dysidea fragilis*, Johnston, a British species very common on the south coast of England, presents one of the best types of this form of fibre. And single grains of sand are frequently to be found among the fibres of the surface of the sponge, elevated on short pedicels of the rapidly growing young fibres, sometimes entirely, and at others only partially, enveloped by the progressing keratode. Figs. 270, 271 and 272, Plate XIV, represent portions of fibre from the same individual.

This genus of sponges appears, to the best of my knowledge, to be the only animals that construct an internal skeleton almost entirely of extraneous matter.

Siliceous Fibre.

This structure is widely different from any of the keratose fibres which contain either secreted silex in the state of spicula, or extraneous silex in the form of sand. The whole substance of the skeleton-fibre consists of solid silex, secreted and deposited in concentric layers, exactly after

the manner of the secretion of pure keratode in the fibres of the sponges of commerce. When cleansed from the sarcodous matter by which they are surrounded in a living state, the fibrous skeleton bears a striking resemblance to fibres of spun glass, and is quite as pellucid and colourless as the artificial material, and the dead sponge quite as brittle. The fibrous skeleton of *Dactylocalyx pumicea*, Stutchbury, in its mode of arrangement strikingly resembles that of one of the sponges of commerce; it is equally complex and irregular in its structure, and the component fibres quite as much anastomosed. In that species the fibres are smooth and cylindrical, but in others they frequently abound with minute, obtuse, wart-like elevations.

There is every indication in the skeletons that the increase in diameter, and the extension in length in the fibres, is effected in the same manner as in the solid keratose fibres. The free terminations of the young fibres have the same attenuated but obtuse form, and the pullulation of the young fibres from the sides of the mature ones is quite as apparent as in their keratose congeners, but they never appear to be in the young state, as the keratose ones frequently are, viscid; and extraneous matters are never detected at their apices, or on their substance.

There are two distinct forms of this class of fibre:

1st. Solid siliceous fibre.

2nd. Simple fistulose siliceous fibre.

The structure of solid siliceous fibre is very similar to that of solid keratose fibre. Occasionally there are indications of a former existence of a minute central canal; but in the fully developed fibre this is rarely visible. The external characters of these fibres vary in each species. In a new siliceous sponge in the British Museum, designated by Dr. Gray *M'Andrewsia azoica*, the fibres are quite smooth, as represented by Fig. 274, Plate XV. But in the greater number of species they are more or less tuberculated, as in Fig. 275, Plate XV, which represents a group of fibres from the type-specimen of *Dactylocalyx pumicea*, Stutchbury, a portion of which is in the possession of Dr. J. E. Gray. In other species in my possession the tuber-

culation is very strongly produced, as represented in a few fibres of *Dactylocalyx Prattii*, Bowerbank, MS., Fig. 276, Plate XV.

Of the second form, simple fistulose siliceous fibre, I know but one example, and that is the remains of the siliceo-fibrous sponge, *Farrea occa*, Bowerbank, MS., on which the beautiful specimen of *Euplectella cucumer*, Owen, is based.

The tubulation of the skeleton-fibre is very similar to that of some varieties of simple fistulose keratose fibre, but the central cavities are not so invariably continuous as in the keratose varieties of fistulose skeleton-fibre. Fig. 277, Plate XV, represents a small piece of the spinulated simple fistulous fibres of the skeleton of Dr. Arthur Farre's specimen. The spinulation of these fibres is a remarkable character. It is the only case of the production of acute spines on the skeleton-fibre of a siliceo-fibrous sponge with which I am acquainted.

Prehensile Fibres.

In the course of my examination of the fibrous skeleton-tissues, I have found but one instance in which they have developed prehensile organs to assist in the attachment of the sponge, and this in a minute siliceo-fibrous species, parasitical on the base of a specimen of *Oculina rosea*, from the South Sea. In this sponge the basal fibres curve downward in the form of numerous small, nearly semicircular reversed arches, from the lowest portions of each of which there is a short stout portion of fibre projected, and at about the length of its own diameter downwards a ring of stout prominent bosses, six or eight in number, is produced, very considerably increasing its diameter at that part; immediately beneath which the fibre is attenuated to a point. These singular organs are admirably calculated to penetrate the porous cavities or fleshy envelopes of the coral, and thus to securely attach the sponge to its adopted matrix (Fig. 278, Plate XV).

CELLULAR TISSUE.

The cellular structures in the Spongiadæ are few and very simple in form. We find no series of conjoined cells in the body of the sponge, as in vegetable tissues. The only forms in which true cellular structures occur in the bodies of sponges, are those of detached spherical molecular cells, and of discoid or lenticular nucleated cells. The first forms are found in abundance on the fibres of many species of the true sponges, and are believed by Dr. Johnston to be the reproductive organs of that genus. They are very minute, not exceeding $\frac{1}{11,000}$ inch in diameter. They are pellucid, and afford no indications of a nucleus, either single or multigranulate (Figs. 315, 316, Plate XXII).

Imbedded in the sarcodous stratum on the interstitial membranes in many of the Halichondroid tribes of sponges, we frequently find numerous compressed circular cells. In the greater number of cases they are so translucent as to readily escape observation even with a tolerably high power; but in other species, as in *Ecionemia acervus*, Bowerbank, MS., a new genus of sponges from the South Seas, in the collection of the Royal College of Surgeons, and in *Halichondria nigricans*, Bowerbank, a British species, these tissues are developed in a more than usually distinct condition.

In the first-named sponge they are thickly dispersed on the surfaces of the interstitial membranes, but without any approach to order or arrangement. They are decidedly lenticular in form, with a well-defined transparent nucleus, which varied in size from about one fourth to three fourths the diameter of the cell in which it was contained. The cells varied considerably in size: the largest I could find was $\frac{1}{3500}$ inch in diameter, and one of the smallest $\frac{1}{10,000}$ inch; but the greater number were about $\frac{1}{7000}$ inch in diameter (Fig. 281, Plate XVI). In *Halichondria nigricans* they do not appear to be quite so convex as in *Ecionemia acervus*, nor are they so numerous as in that species, but they are

somewhat larger in size; one of the largest measured $\frac{1}{2800}$ inch in diameter, and a small one $\frac{1}{5600}$ inch: they are represented *in situ* in Fig. 282, Plate XVI.

The most complete development of cellular structure exists in the genus *Grantia*, where we find them lining the great interstitial cavities of the sponge, as represented in Fig. 312, Plate XXI,—each, probably, in a natural and healthy condition sustaining a cilium. The nucleus in each cell is constantly present, and strikingly apparent when viewed with a power of linear, as represented in Fig. 314, Plate XXI. The only instance with which I am acquainted of a conjoined arrangement of such cells exists in the envelope of the ovaries of *Spongilla Carteri*, the species described by Carter in his 'Account of the Freshwater Sponges in the Island of Bombay,' which that author believed to be *Spongilla friabilis*, Lamarck, but which proves to be a distinct species, which I have named after its discoverer, as a slight recognition of the good services he has rendered to science by his excellent and accurate observations. These cells may be detected *in situ* after the envelope of the ovary has been submitted for a very short time to the action of hot nitric acid, so as to render the coriaceous envelope semi-transparent without destroying it. The structure of its walls is then seen to consist of linear series of cells, six or eight in length, closely packed together in lines radiating from the centre of the ovary to its external surface. They do not appear to be absolutely in contact with each other, but are usually seen to be separated by a thin stratum of a transparent substance, probably an indurated membrane or sarcode. At the surface of the envelope they frequently appear to be somewhat hexagonal from mutual compression. I could not detect a nucleus in any of them (Fig. 284, Plate XVI). Carter and other writers on *Spongilla* have designated the granulated forms of the sarcode in those sponges, "Sponge cells," but I cannot coincide with that opinion. I have frequently tried in vain to detect a proper coat of cellular tissue on the Amœba-like granular masses into which *Spongilla fluviatilis* resolves itself at certain periods of its existence, and neither in a healthy and active

condition, nor in a state of partial decomposition, have I ever been able to satisfy myself of the existence of a surrounding membrane. It appears to me that these bodies are the result of a natural resolution of the sarcode into granular masses of various sizes, each of which, on being liberated from the parent body, becomes an independent gemmule, which is capable of reproducing the species of sponge from which it emanates. And I have long suspected that the Amœbæ found in ponds and rivers, and also in sea-water, are not in reality distinct species of animals, but that they are free portions of the sarcode of various species of Spongiadæ.

ORGANIZATION AND PHYSIOLOGY.

Previously to entering on the subject of the organization and physiology of the Spongiadæ in detail, it will be necessary to take a brief view of the general structure of these animals. Whatever may be their form, or however they may differ from each other in appearance, there are certain points in their organization in which they all agree. In the first place, however variable in its form and mode of structure, there is always a skeleton present on which the rest of the organic parts are based and maintained. Amidst the skeleton, and intimately incorporated with it, are the interstitial canals, consisting usually of two series; the first appropriated to the incurrent streams of the surrounding water, and the second to the excurrent streams, which they conduct from the interior of the sponge to the oscula at its surface, through which they are discharged. In the event of the absence of the excurrent system of canals, their office is served by the great cloacal cavities that are found to exist in some forms of sponges, extending from the base to the most distant parts of the animal. Beside these large cavities, there are others of a much more limited character, the intermarginal cavities, which are situated immediately below the dermal membrane, and which receive the water

inhaled by the sponge, and transmit it to the mouths of the incurrent canals which have their origin in the intermarginal cavities. Enveloping the entire mass of the sponge we find the dermal membrane, in which are situated the pores, for inhalation and imbibition of nutriment, and the supply of the incurrent canals; and the oscula, through which the excrementitious matter and the exhausted streams of water are poured from the terminations of the excurrent canals. These parts are indispensably necessary, and are always present in a living sponge. The attachment of the Spongiadæ to the body to which they adhere during life, is effected by a basal membrane which presents a simple adhesive surface, following the sinuosities of the body on which it is based, entering into holes or cracks and filling them up, thus securing a firm hold of the mass on which they are fixed. When it so happens that the locality consists of sand or mud, their bases frequently assume the form of branching roots, which penetrate the mud or sand to a considerable extent; but they are never instrumental to the nutrition of the animal—they are simply the anchors by which it is fixed to its locality for life.

We will now proceed to consider the structure and functions of these organs in the order indicated at the beginning of this volume, page 4; commencing with

THE SKELETON.

There are two important distinctive characters for consideration in treating of the structure of the skeleton:—1st, the material of which it is constructed; and, 2nd, the mode of its arrangement.

By selecting the material substance of the skeleton as the means of dividing the Spongiadæ into Orders, we obtain three well-defined natural groups, which are again readily divisible into Families, based on the mode of the arrangement of the substance of which the skeleton is composed.

The first Order Calcarea has the primary essential mate-

rial composed of calcareous matter, and this division contains but one group:—

Spicula dispersed without order on membranous surfaces, as in the genus *Grantia* as defined by Johnston.

The second Order, Silicea, comprises those sponges in which the primary essential material of the skeleton consists of siliceous matter. It may be divided into four sections or groups.

1. Those sponges which have the skeleton composed of radiating fasciculi of siliceous spicula, as in *Tethea Dictyocylindrus*, &c.

2. Those in which the skeleton consists of spicula dispersed without order on membranous surfaces, as in *Hymeniacidon caruncula*, Bowerbank.

3. Sponges having the skeleton consisting of spicula cemented together into a network by keratode, as in *Halichondria panicea*, Johnston.

4. Those sponges which have the skeleton composed of solid siliceous fibres, as in *Dactylocalyx pumicea*, Stutchbury.

The third order, Keratosa, consists of those sponges in which the primary essential material of the skeleton is keratose fibre, and this may be divided into three sections:

1. Those which have the skeletons constructed of keratose fibre only, as in the best cup-shaped Turkey sponges of commerce.

2. Those having skeletons of arenated keratose fibre, as in the genus *Dysidea*.

3. Those which have the skeleton formed of spiculated keratose fibre, as in *Chalina oculata*, Bowerbank, and some of the common West Indian sponges of commerce.

In the first group no earthy material of any kind enters into the structure of the skeleton.

The sponges of the second group, by a natural transition, pass into the nearly-allied great division of the Halichondroid skeletons; the inability of the former to secrete silex in an organized form connecting them closely with the purely keratose, while the instinctive habit of appropriating extraneous matters recognises the necessity of other material

in the skeleton beside pure keratode; and the secretion of it by its own inherent power appears to be the next natural step in the development of the animals.

In the third division, those having the skeleton formed of spiculated keratose fibre, the gradual development is also well marked, as in one group we find spicula only in the primary or radiating fibres of the skeleton, while in another group they are found in both the primary and secondary fibres, and are developed simultaneously with the keratode of the young fibres of the skeleton.

1. Calcarea .	*a.* Spicula dispersed on membranes.
2. Silicea . .	*a.* Spiculo-radiate skeletons.
	b. Spicula dispersed on membranes.
	c. Spicula cemented together by keratode.
	d. Solid siliceous fibre.
3. Keratosa .	*a.* Keratose fibre only.
	b. Arenated keratose fibre.
	c. Spiculated keratose fibre.

These divisions afford a general view only of the principal types of the skeleton structure. Other well-defined variations of these divisions, on which the sub-orders will be based, will be pointed out and described at length when we arrive at that portion of our subject in which we shall treat on the classification of the Spongiadæ.

The essential parts of the skeleton of the Spongiadæ are keratode, carbonate of lime, silex, and membrane; and on the different modes of the combination and arrangement of these materials their division into orders, sub-orders, and genera will depend. It will not be necessary to enter here into a detailed account of the structure of these respective parts, as each of them are treated on at length under their respective heads in the portion of this work devoted to organography and terminology. I shall therefore confine my observations to a brief general view of the combinations of the parts essentially necessary to the construction of the skeleton.

Keratode, in its application to skeleton structure, has an exceedingly wide range. In the order Keratosa it is the

most essential element, and in some genera, as in *Spongia*, *Spongionella*, *Verongia*, and *Auliskia*, the skeleton is entirely composed of it, in the form of anastomosing fibres. In other genera the keratose fibres are strengthened either by siliceous spicula or by grains of extraneous matter, selected and incorporated in their structure by the fibres. In the order Silicea it performs a much more subordinate part, appearing only as a cementing material in the formation of the various combinations of spicula of which the skeletons of the sponges of this order are principally composed; but although in these cases only appearing as a subordinate element, it is frequently very abundant. In the order Calcarea it is less in the ascendant than in either of the other orders, and in many species we are scarcely able to distinguish it from the membranous tissues of the sponge. Carbonate of lime, as an element of the skeleton, always presents itself in the form of spicula of various forms in combination with membranous structure.

Silica in the skeletons of the order Silicea, presents itself in a great variety of forms and combinations of spicula. Sometimes the skeletons assume the shape of a beautiful regular or irregular reticulation, composed either of a nearly single series of elongate forms of spicula cemented firmly together at their apices by keratode, or by numerous spicula similarly cemented together, forming a strong and complicated fasciculated thread of reticulations, as in the *Genera Halichondria* and *Isodictya*. In other cases, as in *Tethea* and *Geodia*, we find no reticulated structure, but the spicula are arranged in elongated compound fasciculi, which radiate from either the base or the central axis of the sponge, and in *Dictyocylindrus* we find the reticulate and the radial system both entering into the structure of the skeleton, a modification of the former prevailing in the axis, and the latter existing in the peripheral portion of the sponge. In *Hymeniacidon* neither of these modes of structure exist, the spicula being simply and irregularly dispersed over the membranous base of the skeleton; and finally we find it simulating the form of pure keratose fibre, and becoming a rigid and solid siliceo-fibrous skeleton,

as in the genus *Dactylocalyx*. These are but a few of the numerous varieties of form that exist in the order Silicea, but as the whole of them will be described in detail in the course of the characterisation of the genera, it is unnecessary to enter further into a description of them at present.

The membranous structures as applied to the composition of the skeleton assume generally a much less prominent position than the previously described part, yet in some few genera they are really the principal element. Thus in *Hymeniacidon* they are the primary part of the structure, and the spicula dispersed over their surfaces are the subsidiary portions only; and in *Microciona Hymeraphia* and *Hymedesmia* the basal membrane is the indispensably necessary part of the structure.

SARCODE

Is a pellucid, semi-transparent gelatinoid substance, variable in colour and insoluble in water. It dries readily, and its physical characters are restored by immersion in water with little or no apparent alteration. It is usually spread thinly and rather evenly over the internal tissues, but the surface is rarely perfectly smooth; sometimes it abounds in obtuse elevations, and occasionally separates naturally into innumerable irregularly round or oval masses which are exceedingly variable in size. When examined by transmitted light with a microscopic power of 400 or 500 linear, it is always found to contain innumerable minute molecules of apparently extraneous animal or vegetable matter, the molecules being always more or less in a shrivelled or collapsed condition, and very variable in size. Occasionally it is found abundantly furnished with lenticular nucleated cells, nearly uniform in size, and often highly coloured. Fig. 285, Plate XVI, represents a portion of the interstitial membrane of the honeycomb sponge of commerce, with the sarcode in its natural condition, filled with the remains of the nutrient molecules in a collapsed state. Figs. 281 and 282, Plate XVI, exhibit the same

tissues with the addition of nucleated cells immersed in the sarcode. In the sponges of commerce it is exceedingly largely developed, and nothing can be more different in character than their soft and flexible skeletons and the animal in its natural condition. Specimens of it in this state, which have been preserved in spirit immediately on being taken from the sea, have the whole of their interior nearly as solid and firm as a piece of animal liver; the colour being a very light grey, or nearly white. While the sponge, as a whole, is sensitive and amenable to disturbing causes, the sarcode does not appear to be especially so, as I have frequently observed a minute parasitical annelid which infests the interior of *Spongilla fluviatilis*, passing rapidly over the sarcodous surfaces, and biting pieces out of its substance without apparently creating the slightest sensation to the sarcode, or at all interfering with the general action of the internal organs of the sponge; and in many cases we find foraminiferous and other minute creatures permanently located in its large cavities without appearing to cause it the slightest inconvenience.

When separated from the living sponge, it has at certain periods an inherent power of locomotion; small detached masses of it may be observed slowly but continuously changing their form, and occasionally progressing in different directions; and Carter, in his valuable 'History of the Freshwater Sponges of Bombay,' describes such detached masses of sarcode, when progressing and encountering a fixed point, as dividing longitudinally to avoid the impediment, and again uniting when it has been passed. This gliding motion appears to be dependent on an inherent contractile power, as no cilia appear to have been detected on the surface of such locomotive masses. Dujardin has recorded similar movements in portions of the sarcodous substance from specimens of his genus *Halisarca* (*Hymeniacidon Dujardinii*,) Bowerbank; and similar observations have been recorded by Lieberkuhn and other writers during their observations of the Spongiadæ. I have frequently, at different seasons of the year, taken portions of the sarcode from living and healthy specimens of *Spongilla*, in which I

could not by the closest observation detect these motions, which are so readily to be seen at other periods of their existence; and even at the same period of the year the sarcode of some specimens exhibit these motions, while in others they could not be detected. I have often sought for these phenomena in portions of the sarcode of *Halichondria panicea*, *Hymeniacidon caruncula*, and other marine species, but I have never yet been fortunate enough to detect them. It is highly probable that the capability of such notions exists in the sarcode of these and other marine species for a limited period, but it does not appear that such powers of motion are a constant condition of this substance.

THE SARCODOUS SYSTEM.

The physical characters and the peculiarities of the sarcodous matter of *Spongilla* has engaged the attention of naturalists of late years to a considerable extent, and its inherent vitality and mobile powers have long been known and treated on by many eminent observers; but its general functional powers in the marine Spongiadæ have scarcely received that amount of attention that their importance in the system of the animal demanded. With a view of assisting in the elucidation of these phenomena, I commenced a series of experimental researches on the 'Vitality of the Spongiadæ' in the spring and summer of 1856, at Tenby, where I had every facility for continually observing them in a living and healthy state; and the results of these observations are published in detail in the reports of the British Association for the years 1856 and 1857, at the special request of the Natural History Section. It is unnecessary, therefore, to repeat these observations here, and I shall confine myself accordingly to a few general conclusions arising from the facts developed by previous observations and by my own experiences as detailed in these reports. In thus considering the subject, and on comparing the sarcodous system as it appears in the Spongiadæ with its structure and functions in other and higher,

classes of animals, we must bear in mind that the term sarcode is applied in the sense in which it is employed by Kölliker in his observations on *Actinophrys Sol*, and in accordance with its appearance and functions in the Amœbæ, and not in the more extended sense and general application of the word as applied to muscular masses of flesh. Dujardin has also employed the same term in the same sense many years before Kölliker wrote on these subjects.

As we descend in the organic scale of life, we find the great systems of animal functions, the osseous, the muscular, the nervous, the sanguineous, all becoming simplified, until at last one or more of them is found entirely wanting. But the sarcodous digestive system appears never to be absent. We find it from the highest organized mammals in the form of the mucous lining of the alimentary organs, passing through animals of every degree of development, until the animal itself becomes simplified to the degree of appearing as a mass of gelatinoid sarcode only, or with possibly a central nucleus of membrane, as in *Actinophrys Sol*, &c.

The presence of the stomach has been insisted upon by some naturalists as the organ absolutely necessary to constitute an animal. On the contrary, it would appear, from its functions in the higher animals, that it is at best but a preparatory organ for the less striking but more important one of the sarcodous system which appears invariably to cover the digestive surfaces of animals. In mammals it has hitherto been considered by many physiologists as a subordinate portion of the digestive system, a merely lubricating material to assist the passage of the fæcal matters in its course downwards. On the contrary, if we view it in the light in which it exhibits itself as sarcode, and not as mere mucous effusion, it becomes the ultimate and most important part of the digestive system; the final receptacle, through its wonderful inherent powers of imbibition of the fully elaborated pabulum presented to it, and the ultimate refiner and digester of all the nutriment that is destined to pass into the sanguineous system.

If we examine the digestive surface of the sacular polypi,

of *Actinia*, or of the common *Starfishes*, we find this substance presenting the same unmistakable and peculiar characters, the pellucid, semi-transparent gelatinoid appearance, abounding in molecules and minute vesicles always more or less in a state of collapse. The mucous membranes of the intestines of a mouse which was drowned in warm water to preserve the tissues during examination as nearly as possible in a natural condition, when examined by transmitted light with a microscopical power of 666 linear, presented the same characteristic appearances. Some portions of the mucous lining of the intestine abounded more in the particles than others; they also varied considerably in size, and were all more or less in a state of collapse, and none had the appearance of living and fully distended vesicles. These molecules were not confined to the surface of the mucous or sarcodous matter, but were also embedded at various depths in its substance. They varied considerably in size and character within a small distance. At one place I observed a group of them, each being of, comparatively, a considerable size, while, at a very little distance, there was but very rarely a large particle to be observed, and when they appeared to be of more than average number and size, they were observed to be at the surface of the mucous or sarcodous structure, as if they had not yet been absorbed and lessened in size by the process of digestion. All these circumstances are indicative of the molecules being extraneous to the sarcodous structure itself, and tend to induce us to believe them to be the nutritive matters in course of preparation for final assimilation with the blood after the previous preparatory portions of the process of digestion in the stomach.

These are the general characteristics of the sarcodous system throughout the whole range of the animal kingdom, and, as may naturally be expected, may be traced in the Spongiadæ, however they may differ in their structure and organization. Every cavity in the interior of the animal is coated with a thin stratum of sarcode, over which the incurrent and excurrent streams of water, continually passing through the sponge with a greater or less degree of activity,

are flowing, bearing with them the molecules of animal or vegetable matter that are floating in the surrounding water, and in small specimens of *Spongilla* the molecules, thus imbibed by the pores, may be seen rapidly traversing the tortuous canals of the sponge, being frequently suddenly arrested in their course, and adhering to the sarcodous surface over which they are gliding; and if, while the rapid inhalent process is going on, and an infinite number of extraneous particles of matter are seen entering the pores in every direction, we turn our attention to the excurrent streams from the oscula, we shall be at once struck with the comparatively small number of effete particles that issue from those orifices. While on the contrary, if we examine the oscula while the gentle breathing inhalation only is proceeding—and the nutrient particles are rarely seen entering the pores—we shall not fail to observe that the amount of effete particles ejected from the oscula is still continuing with a regularity that is strikingly indicative of their systematic and gradual liberation from the sarcodous surfaces of the interior of the animal, and it may be further observed that the molecules thus ejected are very much below the average size of those previously imbibed, and that they are always in an exhausted and collapsed condition.

If sections of a sponge in a living state be examined by transmitted light with a power of about 500 or 600 linear, the whole of the sarcodous substance will be seen abounding in the nutrient particles, some simply adhering to the surface, while others are embedded at different degrees of depths, exhibiting all the varieties of form and condition that are so characteristic in the molecules described as existing in the mucous lining of the intestine of the mouse, and in many cases, excepting that in the Spongiadæ, the sarcodous surfaces are somewhat more evenly spread over the membranes on which they repose; such is their similarity, that the two tissues, so distant from each other in the scale of created beings, can scarcely be distinguished from each other under the microscope.

There are other points of similarity existing between the

sarcode lining the interior of the sponge and the so-termed *mucous* lining of the intestines of the higher animals. Under natural circumstances the two substances are insoluble in water, but under the effects of certain stimuli they are each discharged from their natural bases with great facility; and where this discharge prevails to any great extent, it appears to be speedily fatal to the life of the animal. Thus in cases of extreme diarrhœa in warm-blooded animals, immediate prostration of the vital powers is the inevitable result; the final and most important act in the sustentation of the vital powers is greatly interfered with or entirely destroyed, and great prostration of strength or death is speedily the result. The marine Spongiadæ, under ordinary circumstances, may be kept in their natural element, and death may ensue for want of a supply of fresh water, without any remarkable amount of viscous discharge. But if we remove a living specimen of *Halichondria panicea* from salt water and plunge it into fresh water, the result is frequently an immediate and profuse discharge of a glairy gelatinoid matter. The same result may be induced by an addition of a considerable quantity of salt to the sea water in which the animal was contained, or by the addition of a small portion of alum; and when once this viscous discharge has been induced, the life of the sponge is inevitably destroyed. In others of the lower marine animals the same effect is induced by similar causes, and with many of them the immersion in fresh water is notoriously the quickest and most certain mode of destroying vitality, and in these cases the decease is almost always accompanied by an abundant flow of viscous matter. Thus if we have this substance upward from *Actynophrys Sol* to man, through the Spongiadæ and all its other gradations of animal existence, it is always found to be present, and always intimately connected with the digestive process. Especial organs for respiration, nerves for sensation, muscles for motion; all these may apparently be dispensed with in turn, and yet the animal will perform its accustomed functions; but this substance, as mucous lining of intestine, or sarcode, as I have before observed, appears

never to be absent. It even seems to acquire a greater importance in the animal economy as we descend in the scale of beings, until the animal in *Amœba* and *Actinophrys Sol* becomes entirely composed of it; and in these creatures it seems to perform all those varied functions which in other animals are distributed among a numerous set of especial organs. It thus appears to be the most constant and perhaps the most important attribute of animal life. In its most isolated form it apparently supersedes every other organ in the animal. In *Amœba* it appears to exist in its simplest and most isolated condition, it moves by its contractile power, and absorbs nutriment. In *Actinophrys* it adds another function to its list of capabilities, that of throwing out pseudo-tentaculæ by which it entangles and conveys its prey to its surface. In the foraminated animals it develops further powers, it secretes a chambered shell for the protection of its surface, and throws out pseudo-podia by which it moves over comparatively a considerable space in a short period, and anchors itself at its pleasure in any position or locality it may choose to remain in. As we proceed higher in the scale of creation its functions become more limited, but in the act of digestion it always appears to take a most important part.

The internal vital powers of the Spongiadæ seem to be resident in this substance, which appears to fulfil in these animals all the functions of the nervous systems in the higher classes of creation, gifted with elaborately developed nervous systems, and if we view this extraordinary substance in reference to nervous matter, it seems to lead us irresistibly to the hypothesis that they are to a certain extent identical, or that the latter enters in a diffused state into the composition of the former. In plants we have movements resulting from irritation closely resembling those arising in animals from nervous action; but who has ever seen the nerves in plants?

In the dermal membrane of sponges we have actions arising from alarm or injury analogous to those induced by nervous influence, but no nervous filaments can be detected. We naturally ask, why does alarm immediately cause the

closing of the pores in *Spongilla,* and suspend inhalation and imbibition? What unknown cause is it that effects these actions usually dependent on the exertion of nervous energy? In the opening and closing of the defensive cones of spicula in *Grantia ciliata* we have a resemblance of muscular action, without the presence of muscles; but here we have a sufficient cause for the effect in the active vibration of the cilia inducing a flow of water which produces the same results that might otherwise have ensued from muscular action, but we have no such solution to the inherent powers of action in the sarcodous membranes of the Spongiadæ, or in sarcode in its purest and most isolated forms. Whence then comes the power that inspires the action of the cilia in the sponges, if it be not from the sarcode in which their bases, or the cell whence they emanate, are embedded? If the cilia be removed from the animal, enveloped in their surrounding sarcode, their action is continued vividly for a considerable period, but if a single cilium be accidentally separated from the mass, its vibratory motion is almost immediately extinguished; it has been separated from the vital influence that endowed it with action.

But let us return again to the dermal membrane of the Spongiadæ, and its internal lining of sarcode,—what inherent power then is it that renders this wonderfully plastic tissue so sensitive and self-acting. Is sarcode another form of nervous matter? Or is that vital principle infused in sarcode? That it contains an inherent vitality independent of its connexion with other parts of the animal, is distinctly proved by its pure existence in *Actinophrys Sol,* and by its independent action and movements when portions of it are removed from *Spongilla,* or from some of the marine Spongiadæ. If this supposition be true, then the whole of the phenomena of its existence in *Actinophrys Sol,* in the Spongiadæ and in every other form is at once explained. Why should we not have nervous matter without tubular structure surrounding it? If this hypothesis, that sarcode is a diffused form of nervous matter, or that it exists in a diffused form in sarcode, be

true, we have an intelligible solution to an infinite number of phenomena among the lower classes of animals that have hitherto been inscrutable. In the higher classes of animal existence we know well that nervous energy is the spring whence every other vital power proceeds, and we trace the nervous system downward in the scale of animal existences until from a few simple fibres it becomes obsolete; and yet in those creations in which tubular nerves are no longer to be detected life and action is as vivid in proportion to their necessities as in the higher classes, abounding in complicated nervous ramifications. Again, then, we may ask, whence, in the absence of nerves, comes the inspiration of all these vital actions, if it be not that they are due to the inherent nervous properties of sarcode —a never-failing material in animal existences. Every other organ may in turn become obsolete, but sarcode never. It continues its downward course in the chain of existence until it at last becomes the sole representative of animal life.

If under all these various conditions we consider its modes of action, we shall find that its imbibing powers are not exerted continually. In the Spongiadæ, as in all other animals, it has its intervals of action and of rest,* and this habit will perhaps afford us a useful mode of distinguishing between animals and vegetables. Thus in animals the imbibition of nutriment is voluntary and at intervals, while in vegetables it is involuntary and continuous.

THE INTERSTITIAL CANALS AND CAVITIES.

These organs exhibit their most complete mode of development in the genus *Spongia* and in the Halichondroid sponges, occupying nearly the whole of the masses of the animals. They consist of two distinct systems, an incurrent and an excurrent one. The incurrent series have their origin in the intermarginal cavities immediately within the dermal membrane, and their large open mouths receive from these organs the water inhaled through the pores,

* "Report on the Vitality of the Spongiadæ," 'Brit. Assoc. Reports' for 1856, p. 441, &c.

and convey it to the inmost depths of the sponge, ramifying continually like arteries as they proceed in their course downward, until they terminate in numerous minute branches. The inhaled fluid is then taken up by the minute commencements of the excurrent series, which continually unite as they progress towards the surface of the sponge, in the manner of veins in the higher animals, until they terminate in one or more large canals which discharge their contents through the oscula of the sponge. This system is found to obtain in the whole of the genus *Spongia* and in the massive Halichondroid sponges, which have their oscula dispersed over their external surfaces. By this mode of organization the inhaled fluid, laden with nutritive particles, is poured at pleasure into the internal cavities of the sponge, flowing over extensive membranous surfaces coated with sarcode; so that the aggregated surfaces become a great system of intestinal action, fully equal in proportional extent to that of the intestines of the most elaborately organized mammal.

They do not in every genus exhibit the regularity of structure described above, and in some cases the canalicular form resolves itself into a series of irregularly formed spaces. In other cases, where a common cloaca exists, there appears to be but one system of interstitial canals, those which convey the inhaled fluid from the pores through the substance of the sponge to the parietes of the great central cloacal cavity which receives the whole of the fæcal streams, rendering the system of excurrent canals unnecessary.

In the Cyathiform sponges we find a somewhat similar structure. The outer portion of the cup is essentially the inhalant surface, and the interior of it the exhalant one, and there accordingly we generally find a great number of small oscula dispersed on all parts of it, very often having their margins slightly elevated, that the fæcal matter that issues may be discharged free of the surrounding membrane.

The large fistular projections which form such striking and beautiful objects in the genus *Alcyoncellum* are also great cloacal organs, their dermal membranes abounding in pores, and their inner surfaces furnished with oscular orifices,

the intervening space being occupied by the interstitial cavities, the interior forming one large cloacal cavity, which discharges its contents through a cribriform mouth at its distal end. In *Grantia* both systems, the incurrent and excurrent interstitial canals, become very nearly obsolete, the large intermarginal cavities or cells imbibing the water through their pores on the distal extremities, and becoming enlarged and elongated until they reach the parietes of the great central cloaca, into which they discharge their contents, each through a single osculum, into a short depression or cavity in the parietes of the great cloaca, and this shallow cavity represents the nearly obsolete system of excurrent canals.

The membranes lining the incurrent and excurrent canals are frequently highly organized. In the common honeycomb sponge of commerce, when in the same condition as when taken from the sea, these canals are constructed of a series of compound membranes, each consisting of simple interstitial membrane with a layer of primitive fibrous tissue beneath it; the fibrous portion consisting of a single series parallel to each other, and so closely adjoining as to touch each other through nearly their whole course (Fig. 255, Plate XII).

When the fibres are clear of the membranous tissue they appear as simple pellucid threads, but when covered by the membrane they frequently appear as if moniliform; this character seems to be due to minute molecules arranged in linear series on the membrane immediately above them. These membranes abound in large, open, oval spaces, so that the tissue assumes very much the appearance of areolar tissue, as described by Professor Bowman in his treatise on mucous membrane in the 'Cyclopædia of Anatomy and Physiology.'

The layer of membrane forming the surface of the canal has its fibres disposed at right angles to the axis of the canal, while those of the layers beneath it assume various directions, usually in straight lines, excepting in the vicinity of the areas of communication, around which they curve to strengthen their margins.

In the canals deeply buried in the mass of the sponge the sides frequently consist of but one layer of membrane and primitive fibrous tissue, and in this case also the fibres are always disposed at right angles to the axis of the canal, but they are neither so numerous nor so closely packed as in the sides of the great excurrent canals.

The interstitial membranes are also furnished with these fibres, sometimes in considerable quantity, but rather irregularly disposed, while in other cases a single fibre only will be observed meandering across the tissue.

The interstitial membranous tissues in a beautiful little specimen of *Alcyoncellum* from the North Sea, for which I am indebted to my friend Captain Thomas, of the Hydrographical Survey, are very similarly constituted to those of the sponges of commerce. The membranous walls of the interstitial cavities are each formed of a series of fibro-membranous layers, the fibres of each layer being disposed at angles varying from those above and below it.

Figs. 255, 256, 257, and 258, Plate XII, represent portions of the lining membranes of the incurrent and excurrent canals, and the mode of the disposition of the primitive fibrous structure upon them.

INTERMARGINAL CAVITIES.

In the Halichondroid sponges, immediately beneath the dermal membrane, there are numerous and, comparatively speaking, large irregularly formed cavities, which receive the water inhaled by the pores, and convey it to the mouths of the incurrent canals, which have their origin in the deepest portions of the spaces. These organs, from their irregularity in size and form, are not always very apparent, but if a section be made at right angles to the surface in a dried specimen of *Halichondria panicea* or *Chalina simulans*, Bowerbank, they may be readily detected and distinguished from the interstitial canals and spaces of the sponge.

Fig. 300, Plate XIX, represents a section of *Halichon-*

dria panicea, and Fig. 299, Plate XIX, a similar section of a branch of *Chalina simulans,* Bowerbank, showing that, however varied the forms of the sponge may be, the interstitial cavities are the same in structure and position.

I have never been able, in the Halichondroid sponges, to detect valvular diaphragms separating these spaces from the interstitial canals and cavities beneath.

In the genera *Geodia* and *Pachymatisma* these organs assume a very much greater degree of regularity and a complexity in their organization that are never apparent in those of the Halichondroid sponges. In *Geodia Barretti,* Bowerbank, MS., a highly organized species of the genus, they are found in the crustular dermis in great abundance. They are in form very like a bell, the top of which has been truncated. They are situated in the inner portion of the dermal crust; the large end of the cavity being the distal, and the smaller end the proximal one. The open mouth or distal end of the cavity is not immediately beneath the dermal membrane. There is an intervening stratum of membranes and sarcode, of about two-fifths the entire thickness of the dermal crust, which is permeated by numerous minute canals which convey the water inhaled by the pores to the expanded distal extremity of the cavity. The proximal end is closed by a stout membranous valvular diaphragm, which the animal has the power of opening and closing at its pleasure. It is usually entirely destitute of the characteristic dermal spicula that are found abundantly in the adjoining membranous tissues.

The action of the diaphragm of each cavity appears to be independent of the surrounding ones, the condition or degree of opening of no two adjacent ones being alike. In the greater number of cases they were in a closed state, and in this condition the membrane was filled with concentric circles composed of minute rugæ or thickened lines, and at the centre it was closely pressed together, completely closing the orifice. In some cases the membrane was only partially closed, and the orifice was either circular or slightly oval; in others it was nearly as large as the diameter of the basal end of the cavity. The pursing of the centre

of the membrane of the diaphragm was always outward as regards the cavity, so that when viewed from within it appeared as a slightly funnel-shaped depression, the bottom of which was conical. The cavities are lined by a smooth and tolerably strong membrane, abundantly supplied with slender fibrous tissue, disposed in nearly parallel lines at right angles to the long axis of the cavity.

The adaptation of the skeleton to the support of these elaborately constructed organs is very remarkable. The sponge is furnished abundantly with large expando-ternate spicula, the radii of which are furcated at their apices. They occur in a series of bundles; the long attenuated shafts of each fasciculus approximate at their bases, and diverge thence until the ternate head of each is about equally distant from its surrounding neighbours, and the extremities of the rays touch or slightly cross each other, thus forming a beautiful and regular network, the meshes being six- or seven-sided, according to circumstances. The upper surfaces of the radii are firmly attached to or partially imbedded in the under surface of the crustular stratum, and the areas thus formed are occupied each with the proximal valvular terminations of one of the intermarginal cavities.

The progressive development of these inhalant areas, formed by combinations of the radii of the ternate forms of spicula in different species of sponges, is very interesting. In *Pachymatisma* they are so indefinite that they can scarcely be said to exist. The ternate spicula are few in number, and very irregular in their mode of disposition, and a faint indication only of their future regular combination to form the dermal reticulation is apparent. In the more highly organized genus *Geodia* we find them in different species in progressive stages of combination, until, in *G. M'Andrewii* and *Barretti*, the apices of the radii of the ternate spicula are interlaced with each other, and a continuous irregular network is formed, each area of which is filled with the proximal termination of an intermarginal cavity. In *Dactylocalyx Prattii*, Bowerbank, MS., the structure advances another stage towards perfection.

There is the same design as that exhibited in the construction of the dermal areas in *Geodia M'Andrewii* and *Baretti*, but there is a considerable difference in the application of the areas produced by the combinations of the ternate apices. In *Geodia* these areas are placed beneath the highly organized and regularly formed intermarginal cavities, and form the framework and support of their valvular proximal ends; while in *Dactylocalyx Prattii* they are situated above the distal ends of the intermarginal cavities of the sponge, which have not the regular structure and valvular appendage of those of *Geodia*, but are similar to the like organs in the Halichondroid sponges, and in this position they serve only to support and strengthen the dermal membrane, which adheres firmly to their distal surfaces. In this situation they are subject to a greater chance of pressure and disruption than in the more deeply seated ones of *Geodia*, and accordingly we find extra provisions for the safety of the junctions of their radii. The shafts of these spicula are short, stout, and conical, and they penetrate but a very short distance into the substance of the sponge. They do not appear to be cemented to any part of the rigid siliceo-fibrous skeleton, but are merely plunged into a somewhat thick stratum of membranous structure reposing on the surface of the skeleton. Their radii are compressed considerably and extended laterally, so that their planes are in accordance with that of the dermal membrane, and they present a greater amount of adhesive surface than those having cylindrical radii. The ternate rays ramify irregularly. Sometimes one ramus, after slightly pullulating, remains nearly obsolete, causing the branch to assume a geniculated form, like some of the ramifications of a deer's horn, and no two appear to be exactly alike; in fact, there is every appearance that each ray is influenced and modified in its development by the necessities of combination with the adjoining spicula, and their apices are directed in such a manner that they lap over each other in opposing lines, so that each two form a spliced joint, giving a much greater amount of strength than the mere crossing of the radii at various angles, as in those of *Geodia*. The inhalant areas

thus formed appear to differ very slightly from those of *Halichondria panicea*, in each of which several pores are opened, while those of *Dactylocalyx Prattii* seem to be devoted each to a smaller number (Fig. 306, Plate XXIX).

As the ternate spicula thus united for the support of the dermal membrane would afford it little or no protection against the voracity of its smaller enemies, we find the necessary defence in innumerable short, stout, entirely spined, cylindrical spicula, not exceeding $\frac{1}{3000}$ inch in length; thus minute, there is no conceiving a predaceous creature with a mouth so small that they would not enter and become a subject of annoyance so great as to interfere seriously with its attacks on the membrane; and they are so numerous, and so closely packed together, that no portion of it equal in size to the length of a spiculum could be removed without one or two of them accompanying it.

A still further advance in this system of dermal support and defence is exhibited in the beautiful harrow tissue of Dr. A. Farre's siliceo-fibrous sponge, *Farrea occa*, Bowerbank, MS., to which his specimen of *Euplectella cucumer*, Owen, is attached. In this case we have a perfect and regular quadrilateral network of smooth siliceous fibre, from the angles of which a double set of short, conical, spicular shafts are projected, each about $\frac{1}{120}$ inch in length and entirely spined. Each set are at right angles to the plane of the network, one series pointing inward and serving the purposes of attachment to the mass of the sponge beneath, while the other set are directed outward, serving as defensive weapons; so that a small piece of this tissue beneath the microscope closely resembles an agricultural harrow, with the difference that it has two sets of teeth in opposite directions instead of one. The dermal membrane has been nearly all destroyed; but entangled with the fibres of the skeleton there are some attenuato-stellate spicula, with which it is probable the dermal membrane was amply furnished as secondary defences against its minute enemies.

I believe the surface presented to the eye in the portion represented by Fig. 311, Plate XXI, to be the external

surface, as the fragments of the dermal membrane which remain all seem to cover that side of the fibres. Generally speaking, there is some difficulty in detecting the double series of spicular organs at the angles of the network, but a reversal of the object beneath the microscope immediately removes all doubt on that subject.

In *Grantia compressa* and *ciliata* the intermarginal cavities appear to attain their highest degree of development, and are multiplied and expanded to such a degree as to almost supersede every other organ. The whole sponge in these species is formed of a great accumulation of elongated cells or cavities, closely adjoining each other and angular by compression. Their conical distal terminations, abounding in pores, represent the external surface of the sponge, while their valvular proximal ends form the inner surface, in conjunction with the shallow cavities, into the distal ends of which each cell discharges its contents. These shallow depressions, intervening between the intermarginal cavities and the cloaca, are all that remains to represent the incurrent portion of the interstitial systems so largely developed in the Halichondroid sponges, the great cloacal cavity entirely superseding the excurrent spaces and canals (Figs. 312 and 313, Plate XXI).

In these species of *Grantia* there is no doubt regarding the existence of cilia, the whole of these great cavities being completely lined with them.

It is a question whether the intermarginal cavities share, in common with the interstitial canals, in the function of the assimilation of nutriment, or whether they are devoted solely to the aëration of the fluids of the animal; and this, if we consider the structure and extent of the interstitial canals in the Halichondroid sponges, is probably the case. In *Grantia* the abundant provision of cilia in those cavities at once stamp them as breathing organs; and although cilia have never yet been satisfactorily proved to exist in the intermarginal cavities of the Halichondroid sponges, there can be no reasonable doubt of their being the homologues of the large ciliated cavities in *Grantia compressa* and other similarly constructed sponges. Now, in these

sponges, although the cilia may be readily seen in vivid action within the open oscula, as I have described at length in my paper "On the Ciliary Action of the Spongiadæ," published in the 'Transactions of the Microscopical Society of London,' vol. iii, p. 137, not the slightest trace of cilia exists without those organs; and this seems to indicate that the aërating functions were strictly confined in these sponges to the large intermarginal cavities.

The same mode of reasoning applies equally well to the intermarginal cavities of *Geodia* and *Pachymatisma*, to which it is probable that the cilia are in like manner confined. The great valves at the proximal ends of these cavities in this tribe of sponges appear to strongly indicate a decided separation of the functions of aëration and digestion; and if this conclusion be true in regard to the inter-marginal cavities of *Geodia* and *Pachymatisma*, it will probably be so in the homologous organs in *Grantia;* and in this case we must look for the digestive surface in the shallow cavities intervening between the terminal valve of the intermarginal cavities and the parietes of the great cloaca, and of the surfaces of that organ itself. The structure and functions of the intermarginal cavities, and especially as displayed in *Geodia* and *Pachymatisma*, indicates a closer alliance with the great class Zoophyta than has hitherto been suspected to exist. In the one case we have an accumulation of individual animals conjoined in one mass; in the other, a similar congregation of organs in place of individuals.

DERMAL MEMBRANE.

The dermal membrane envelopes the sponge entirely. When denuded of sarcode by partial decomposition, it has the appearance of a simple, pellucid, unorganized membrane. In the living state its inner surface is somewhat thickly coated with sarcode, and it has the appearance of, comparatively speaking, a stout, tough skin, and in many sponges it requires a considerable amount of violence to

tear it. The dermal membrane of the Turkey sponge of commerce, *Spongia officinalis,* is abundantly supplied with primitive fibrous tissue. It curves round the margins of the porous areas, thickening and strengthening the whole of the dermis to a very considerable extent, but it exists to a very slight extent in the pellucid membranes of the areas in which the pores are opened. When alive, it is replete with powers of life and action of a very remarkable description. Without the slightest appearance of nerves or muscles, it has the power of opening pores on any part of its surface, and of closing them again at pleasure, without leaving a trace of their existence to indicate the spot they occupied; and there is no amount of laceration or destruction that it does not seem capable of repairing or replacing in a very short period, reproducing itself over extensively denuded surfaces in a very few hours. It also shares, in common with the interstitial membranes, the power of strongly and quickly adhering to other sponges of the same species with which it may be brought in contact, but never with those of a different species, however long the two may remain pressed against each other. In some sponges the distal extremities of the skeleton pass through and project beyond the surface of the dermal membrane, while in other cases the whole of the skeleton is confined within it.

I will not describe at length these remarkable powers of the dermal membrane, but refer the reader to a series of observations on the "Vital Powers of the Spongiadæ," published in the 'Reports of the British Association' for 1856, p. 438, and for 1857, p. 121, in which I have described in detail a series of observations and experiments on living sponges, which demonstrate in a satisfactory manner the extent of the vital powers and capabilities of this highly sensitive membrane.

In some species of sponges the outer surface of the skeleton is especially modified to strengthen and support the dermal membrane. Thus, in some of the keratose sponges of commerce, in parts of the sponge which have been in contact with other sponges, or with rocks or stones, we find a fine network of stout fibres immediately beneath

the dermis, as represented by Fig. 310, Plate XX, and *Isodictya varians*, Bowerbank, is always furnished with a fine network of spicula, the reticulations consisting of a single series of spicula only, and on this framework the dermal membrane is firmly cemented. Fig. 309, Plate XX, represents a small portion of this dermal reticulation, magnified 108 linear.

In *Halicondria panicea* the same description of reticulation prevails, but in this sponge the fibres of the network are always composed of numerous spicula cemented together, as represented in Fig. 303, Plate XIX, illustrating the porous system of the above-named species of sponge. But this regularity of structure is not constant even in the same individual; thus, in *Hal. panicea* you will often observe one portion of the dermis beautifully reticulated, while a closely adjoining spot will be supported by a series of matted spicula, without any indication of areas for the pores, and these variations in structure are evidently determined by the presence or absence of those organs at particular parts of the surface. In other cases, beside a general attachment of the inner surface of the dermal membrane to the surface of the skeleton, we find it supported by numerous flat fasciculi of spicula dispersed irregularly on its inner surface, and differing materially in size and form from those of the skeleton, as in our common British species, *Halichondria incrustans*, Johnston. Great variety exists in these modes of strengthening and supporting the dermal membrane; but those which I have described above will suffice to illustrate the general principles of their application. Beside the general systems of external defence, the dermal membrane is often supplied with special defences. Thus, in *Tethea muricata*, Bowerbank, MS. (Figs. 304 and 305, Plate XIX), we find its outer surface abundantly supplied with elongo-stellate spicula, which project externally to a considerable extent; and in *Dictyocylindrus stuposus*, Bowerbank, beside the numerous defensive spicula projected through the surface, we find the membrane filled with minute sphero-stellate spicula, which would effectually protect it from the assaults of any minute enemies that

might attempt to prey upon it. Fig. 298, Plate XVIII, represents a small portion of the dermal membrane of this sponge. This mode of defence is very general in the genera *Geodia*, *Tethea*, and *Pachymatisma*, and it occasionally occurs in other genera of Spongiadæ.

THE PORES.

The pores in the Spongiadæ are the orifices or mouths through which the animals breathe and imbibe their nutriment. They are situated in the dermal membrane, and are exceedingly numerous when the imbibing powers are in full operation. In *Pachymatisma* and *Geodia*, and in some other highly organized genera, there is good reason to believe that they are permanent organs, opening and closing repeatedly in the same situations. But in the greater part of the Halichondroid types of sponges they are certainly not permanent orifices, like the mouths of higher classes of animals, and in these sponges, when they are in a state of complete repose, there is not the slightest indication of their existence. Their usual form is circular, but they frequently assume the shape of an elongated oval, and within a limited range they vary to a considerable extent in their dimensions ; on the whole, they exhibit a very constant and universal type of form and size ; however different may be the internal structure of the sponges, or however great may be the difference in size of the individuals, they always appear to maintain their normal characters. No definite law appears to prevail in their distribution over the surface of the sponge, and they are liable to appear to a greater or a less extent on every part of its external surface, wherever there are intermarginal cavities beneath. The situations where they may be expected to appear may in many instances be readily recognised. Thus, in *Halichondria panicea*, wherever we see on the dermal membrane a well-defined reticulation of spicula, with clear and distinct areas, there, when the sponge is inhaling, we may expect to find the open pores, as represented in Fig. 303, Plate XIX,

while on spots perhaps immediately adjoining where the dermal membrane is occupied by a thickly interwoven mass, a felting of spicula, the probability is that not a single pore can be detected.

In some of the West India fistulose sponges we find the large or primary area of the dermal surface composed of keratose fibre, and within these large areas the dermal membrane is strengthened and supported by a secondary reticulation of spicula, in the areas of which the pores are opened. In these secondary reticulations the spicula are abundant, while in other parts of the sponge the tension spicula are rather of rare occurrence. In *Grantia*, a sponge of a widely different construction to those of the Halichondroid type, they occupy the distal extremities of the large intermarginal cavities of the sponge, and they appear to open over the whole of those portions of the cavities not in contact with the adjoining ones.

In *Pachymatisma Johnstonia*, Bowerbank, a British sponge closely allied to the genus *Geodia*, we find the dermal membrane perforated by innumerable pores, some as minute as $\frac{1}{1000}$ inch in diameter, while others attained the size of $\frac{1}{230}$ inch. They are nearly equidistant from each other, but without any order in their arrangement. Immediately beneath the dermal membrane there is a stratum of membranous structure and sarcode destitute of ovaries, and about equal in thickness to one third of that of the whole of the dermal crust, the remaining two thirds of which consists of a stratum of ovaries closely packed together, but perforated at intervals by the intermarginal cavities. Through the upper stratum, destitute of ovaries, a small canal passes from each pore to the nearest adjacent intermarginal cavity, so that there are a series of them at various angles, all concentrating their streams of inhaled fluid at the distal end of the cavity, which is gradually expanded in diameter to receive them. In these sponges, therefore, each mouth appears to be furnished with a separate œsophagus, if I may be allowed the term, connecting it with a stomach-like cavity, common to a group of mouths above it; a system of organization strikingly in unison with that of the

higher classes of animals. In some cases, as in *Geodia M'Andrewii* and *Barretti*, Bowerbank, MS., we find the pores systematically congregated in groups, as in Fig. 302, Plate XIX, which represents two groups from the latter species, and this congregation is accounted for by the peculiarities of the form and arrangement of the intermarginal cavities of that class of sponges.

In my "Further Report on the Vitality of the Spongiadæ," published in the 'Reports of the British Association' for 1857, I have described at length the opening and closing of the pores in *Spongilla fluviatilis;* each operation is commenced and terminated in less than a minute; they are perfectly dependent on the will of the animal, and in neither case are they simultaneous, but follow in irregular succession, in accordance with the necessities of the animal; and when once closed, they do not appear to ever open again in precisely the same spot.

In these wonderful opening and closing operations in the dermal membrane of *Spongilla*, every movement is accomplished as systematically and accurately as if there was a perfect system of nerves and muscles present, while not a vestige of fibrous structure can be detected in the thin translucent membrane and its sarcodous lining. No cicatrix remains for an instant after closing, no indication of the spot where the opening is the next moment to be effected.

In sponges exposed to the action of the atmosphere, between high- and low-water marks, and in dried specimens, the pores can rarely be detected. In the first case they are carefully closed on the receding of the tide, that the water within them may be safely retained during their exposure to the atmosphere, and in the latter case the violence offered to it, and the shock of its removal from its native locality, is sufficient to induce an immediate closing of those organs, as I have shown in the details of my observations on these organs in *Spongilla* in the volume of the 'Reports of the British Association' for 1857, to which I have before alluded. But should a specimen of marine sponge, after a careful removal from its place of growth, be

placed in a shallow pan of sea-water, and be allowed to die of inanition, it then frequently expires with the whole or a considerable portion of the pores open, and in that state it may be readily preserved for the cabinet.

THE OSCULA.

The oscula are the fæcal orifices of the sponge. They are situated at the distal terminations of the single or concentrated excurrent canals of the animal. They vary considerably in form and size; sometimes they appear as single large orifices, while at others they consist of several small orifices grouped together. When the sponges are massive and solid, they are usually to be found dispersed over the dermal surface, but occasionally they are grouped on the highest portions or on the elevated ridges of the mass. In *Geodia Barretti*, Bowerbank, MS., they are concentrated in deep depressions or pits. In other cases they are entirely hidden from the view, lining the interior of elaborately constructed cloacæ, situated in the centre of the sponge, as in *Grantia compressa* and *ciliata*, *Verongia fistulosa*, and a numerous series of species of fistulose sponges from the West Indies.

They are permanent organs, and are capable of being opened or closed at the will of the animal, and are subject to a considerable amount of variation in size and form, in accordance with the variations in the actions of the sponge. Thus in littoral sponges they are frequently entirely closed, and their situation even quite indeterminable during the period of their exposure to the air; but when immersed in water, and the sponge is in the energetic action of the imbibition of nutriment, they are expanded to their full extent; but when this action ceases and that of gentle respiration only exists, many of them close entirely, and others exhibit apertures not exceeding half their former diameters, while the imbibition of nutriment was in vivid action. Their expansion or contraction is not rhythmical; each can be opened or closed at the will of the sponge without any

apparent effect on the others. Nor is the habit of opening and closing the oscula the same in every species. Thus in the course of my observations on *Halichondria panicea* and *Hymeniacidon caruncula* in their natural and undisturbed localities, I have frequently observed during their exposure to the air at low tide, that while no oscula in an open condition could be found in *Hymeniacidon caruncula*, the greater portion of those on the specimens of *Halichondria panicea* were more or less in an open state.

They appear also to be subject to a considerable amount of modification as regards situation, even in the same sponge. Thus in our common British species, *Halichondria panicea*, when of small size, they are situated on the surface of the sponge, and are scarcely, if at all, elevated above the dermal surface; while in large specimens of the same species we find them collected in the insides of large elongated tubular projections or common cloacæ, and these organs vary from a few lines only in height and diameter to tubular projections several inches in height, with an internal diameter of half or three fourths of an inch. When they attain such dimensions their parietes are often of considerable thickness, and their external surface becomes an inhalant one, like that of the body of the sponge.

In many species the oscula are always elevated above the dermal surface, and these thin pellucid elevations are permanent, while in others, as in *Spongilla fluviatilis*, the tube exists only during the course of the energetic excurrent action; and in such cases it appears to be subject to great variation in size and form, as I have shown in the description of *Spongilla* in my "Further Report on the Vitality of the Spongiadæ," 'Reports of the British Association' for 1857.

INHALATION AND EXHALATION.

The works of the old writers on Natural History are full of vague opinions on the nature of sponges, but none of them seem to have seriously studied their anatomy, or to

have kept them alive in sea-water and examined their daily habits. They appear to have excited abundant attention in the closet, and but very little in their natural localities. Their ideas are so loose and indefinite that it would really be a loss of time to seriously examine and attempt to refute them; and as Dr. Johnston, in his 'History of British Sponges,' has given in his Introduction, Chapter II, an excellent digest of the various opinions of the previous writers on the subject, I shall content myself with referring my readers to the work of that eminent author for further information on these subjects, and of briefly referring to the few actual observations that appear to have been made by naturalists.

Marsigli, at the beginning of the eighteenth century, has stated that he had seen contraction and dilatation in the oscula of several sponges just removed from the sea.

After Marsigli, Ellis (Ellis and Solander), pp. 184, 186, and 187, (see also 'Zool. Journ.,' pp. 375, 376,) enunciated similar opinions founded on his own observations on the action of the oscula and their currents; but neither of those authors was aware of the true mode of the entrance of the water into the sponge—a much more difficult problem to solve than its exit through the oscula.

Cavolini, in his researches, although made on sponges recently taken from the sea, failed in seeing the action of the oscula as Ellis had done, and he accordingly disputed their truth. At a later period, Colonel Montagu, although actually examining them in the places of their growth, arrived at similar conclusions to those of Cavolini, and, like that author, he believed them to be animals of a very torpid nature. Montagu's reasoning to prove the animality of sponges is for the most part sound and excellent; he says: "Whether motion has ever been discovered or not in any species of sponge, is not, I conceive, of so much importance as some naturalists would appear to consider. Those who are solicitous in their inquiries after the animals which they have supposed to construct the vesicular fabric of sponges, have expressed their surprise that in this age of cultivated science no one should have discovered them, must have

taken a very limited view of matter possessing vitality, and have grounded their hypothesis only upon supposed analogy." He also observes, "The true character of *Spongia* is that of a living, gelatinous flesh, supported by innumerable cartilaginous or corneous fibres or spicula, most commonly ramified or reticulated, and furnished more or less with external pores or small mouths which absorb the water, and which is conveyed by an infinity of minute channels or capillary tubes through every part of the body, and is there decomposed and the oxygen absorbed as its principal nourishment, similar to the decomposition of air in the pulmonary organs of what are called perfect animals."—'Wernerian Memoirs,' vol. ii. pp. 74, 75.

Lamouroux's conclusions regarding the nature of sponges are so thoroughly vague and supposititious as scarcely to require notice.

Lamarck has placed the Spongiadæ in a higher position than any naturalist who had preceded him, giving them precedence of the sertularian and celliferous corallines, and even of the corallidæ; but I cannot concur with him to the full extent of his conclusions, which, like those of most previous writers, were derived to a much greater extent from comparative reasoning than in actual observation of the animals in a living and natural condition.

Professor Schweigger's opinions are very much more those of a practical naturalist, and it is evident that he had closely observed them in a living condition; but he too shares the erroneous opinion of his predecessors, that the oscula were the organs of imbibition, and that no water entered through the dermal surface. Professor Bell, in the 'Zoological Journal' for June, 1824, states that he saw the action of the streams from the oscula, but, like previous writers, concluded that they were organs of imbibition as well as excurrent organs. And it was not until the excellent and accurate "Observations and Experiments on the Structure and Functions of the Sponge" were published in the 'Edinburgh Philosophical Journal,' vols. xiii and xiv, by Professor Grant, that a correct notion was entertained by naturalists of the inhalant and exhalant powers of those

bodies. These details by the learned Professor are so full and complete as to leave but little room for the improvement of our knowledge of this portion of their natural history. And the facts of the imbibition of the surrounding water by the pores in the dermal membrane, its circulation through the internal cavities of the sponge, and its final ejection through the oscula, has been firmly established and acknowledged by all naturalists who have studied these animals closely in a living state. Dr. Grant has, in truth, proved himself to have been, in regard to the aqueous circulation in the sponge, what Harvey was to that of the blood of the higher classes of animal life, the first to discover and to publish the true mode of the circulation of the water in the animal.

This learned and accurate observer says, "I first placed a thin layer from the surface of the *S. papillaris*, in a watch-glass with sea-water under the microscope, and on looking at its pores I perceived the floating particles driven with impetuosity through these openings; they floated with a gentle motion to the margin of the pores, rushed through with a greatly-increased velocity, often striking on the gelatinous networks, and again relented their course when they had passed through the openings. The motions were exactly such as we should expect to be produced by cilia disposed round the inside of the pores."—'Edinburgh New Philosophical Journal,' vol. ii. p. 127.

The same author, in describing the excurrent action, says, "The *Spongia panicea* (*Halichondria incrustans*, Johnston) presents the strongest current which I have yet seen." Two entire round portions of this sponge were placed together in a glass of sea-water with their orifices opposite to each other, at the distance of two inches; they appeared to the naked eye like two living batteries, and soon covered each other with feculent matter.

Stimulated by the recital of the observations of Dr. Grant, I have often sought these currents flowing from the oscula, and there is no species in which I have had the opportunity of examining in a fresh and vigorous condition in which I have not succeeded in seeing them. In the

one observed by Dr. Grant, *Halichondria incrustans*, Johnston, the oscula being few in number and very large, the excurrent streams are more than usually powerful. In the course of my investigations "On the Vitality of the Spongiadæ," at Tenby, which are published in the 'Reports of the British Association' for 1856, and in the "Further Report," published in the same work for 1857, I have described a long series of observations of the vital actions of the Spongiadæ as displayed in *Hymeniacidon caruncula* and *Spongilla fluviatilis*, in both of which species there was a perfect accordance in the habits and modes of exertion of these vital actions.

The power of inhalation appears to be exerted in the Spongiadæ in perfect accordance with the similar vital functions in the higher classes of animals, not involuntarily and continuously as in the vegetable creation, but at intervals, and modified in the degree of its force by the instincts and necessities of the animal. And it may be readily seen that the faculty of inhalation is exercised in two distinct modes; one exceedingly vigorous, but of comparatively short duration, the other very gentle and persistent. In the exertion of the first mode of inhalation, that is during the feeding period, a vast number of pores are opened, and if the water be charged with a small portion of finely-triturated indigo or carmine, the molecules of pigment are seen at some distance from the dermal membrane, at first slowly approaching it, and gradually increasing their pace, until at last they seem to rush hastily into the open pores in every direction. In the meanwhile the oscula are widely open, and pouring out with considerable force each its stream of the excurrent fluid; and if the reflection of one of the horizontal portions of a window-frame be brought immediately over an excurrent stream, it will frequently be seen that the surface of the water is considerably elevated by its action, even although the osculum be half or three fourths of an inch beneath its surface, and this vigorous action will sometimes be continued for several hours, and then either gently subside or abruptly terminate. Occasionally a cessation of the action may be observed in some

of the oscula, while in others it is proceeding in its full vigour, and sometimes it will be suddenly renewed for a brief period in those in which it had apparently ceased. These vacillations in the performance of its functions is always indicative of an approaching cessation of its vigorous action. When the vivid expulsion of the water has ceased, the aspect of the oscula undergoes a considerable change; some of the smaller ones gradually close entirely, while in the larger ones their diameters are reduced to half or one third of what they were while in full action. Simultaneously with the decline in the force of the excurrent action the greater portion of the pores are closed, a few only dispersed over the surface of the sponge remaining open to enable the gentle inhalation of the fluid to be continued, which is necessary for the aëration of the breathing surfaces of the sponge. The breathing state of inhalation appears to be very persistent, and I have rarely failed in detecting it when I have let a drop of water, charged with molecules of indigo, quietly sink through the clear fluid immediately above an open osculum. These alternations of repose and action are not dependent on mere mechanical causes, and sponges in a state of quiescence may be readily stimulated to vigorous action by placing them in fresh cool sea-water, and especially if it be poured somewhat roughly into the pan, and agitated briskly for a short period; and this will take place even in specimens that have very recently been in powerful action.

No general law seems to guide the animal in the choice of its periods of action and repose, and no two sponges appear to coincide entirely in the time or mode of their actions. In fact each appears to follow the promptings of its own instinct in the choice of its periods of feeding and repose.

In the littoral sponges there is a third condition of the animal, and that is during its exposure to the atmosphere in the intervals between high and low water, and in some sponges the pores and oscula are both completely closed. But this condition does not obtain in all species. Thus, during the course of my investigations at Tenby, I observed

that while amidst the numerous specimens of *Hymeniacidon caruncula* and *Halichondria panicea* that covered the rocks in the neighbourhood of St. Catherine's Cave the former rarely exhibited an open osculum in the absence of the water, those of the latter species were frequently more or less open.

The most beautiful and striking view of the differences existing between vigorous action and the comparative repose of the breathing process is exhibited in *Grantia ciliata*. In this species the pores are situated on the obtusely conical distal terminations of the intermarginal cells or cavities, each of which is furnished with a long fringe of spicula surrounding its porous end (Fig. 345, Plate XXVI), their proximal terminations being cemented, for about a third of their length, to the slightly curved surface of the base of the cone. In the state of the comparative repose of aërating inhalation, and when the base of the conical extremity of the cavity is not distended by the incurrent action, these spicula all converge to a point at the level of their own apices, and the water thus gently inhaled passes between the shafts of the spicula, forming the protective cone to the inhalent pores and effectually preventing any extraneous matter from approaching them. But when the vigorous feeding action commences, the distention of the base of the conical portion of the cavity brings it into lines parallel to the axis of the cell, and thus the conical fringe of spicula assumes a cylindrical form, and the molecular food of the animal is freely admitted to the pores.

A corresponding action obtains in the exhalant system of this interesting sponge. The mouth of the great central cloaca is furnished with a thick fringe of very long and slender spicula, which by the contraction of its sides near the mouth are all brought to assume a conical form like those appended to the inhalant cavities; but when the inhalant action is in vigorous operation, and the oscula are all pouring their streams into the cloaca, the force of the water thus accumulated distends the mouth of the cloaca to such an extent as to cause the fringe of long spicula to assume the form of an open cylinder, or in some cases it is expanded

to such an extent as to become slightly funnel-shaped, and in this condition the fæcal stream may be seen issuing from it with considerable force. There are many other interesting points in the structure of this highly organized and interesting sponge which I will not advert to at length, but refer my reader to a fuller and more complete history of its structure published by me in the 'Transactions of the Microscopical Society of London' for 1859, vol. 7, p. 79, Plate V.

Thus we find that inhalation is the primary vital operation induced by ciliary action, and that exhalation is merely a mechanical effect arising from the primary cause. We find also that these actions are separated into two distinct modes; the one exceedingly active and vigorous, exerted only at intervals and for short periods, and the other gentle and continuous. If we combine the consideration of these peculiarities of function with those of the anatomical structure, we find that the incurrent streams are always received in intermarginal cavities, and that these organs, however modified, are always present, and in some cases can be distinctly and strikingly separated from the great mass of the interstitial canals and cavities of the sponge. If we trace the course of the inhaled fluids, we find that on their entrance through the pores they are first brought into contact with the parietes of the intermarginal cavities, and passed thence into the complicated system of digestive surfaces which line the incurrent and excurrent canals and cavities of the sponge, and that the exhausted fluids charged with fæcal matters are finally discharged without the slightest return to or intermixture with the contents of the intermarginal cavities. We may therefore, it appears to me, safely conclude that the respiratory and digestive functions are separated, and that the latter has its seat in the intermarginal cavities, and the former in the interstitial canals and cavities.

The vital energy of the Spongiadæ must be very considerable, and the quantity of oxygen consumed by their respiration great, if we may judge by the effects of their presence in the vivarium, where their introduction makes

sad havoc among the other inhabitants, few being able to withstand their deleterious presence, and without a large supply of water and a frequent change of it they themselves quickly expire of exhaustion.

NUTRITION.

In treating on the subjects of inhalation and exhalation, I have described the energetic period of action in the sponge during the imbibition of the surrounding fluid as equivalent to the operation of feeding in the higher classes of animals. And in my "Further Report on the Vitality of the Spongiadæ," published in the 'Reports of the British Association' for 1857, p. 121, I have described the results of feeding a small specimen of *Spongilla fluviatilis* with finely comminuted indigo in water, and I have there stated that "many of the molecules might be readily followed, as they meandered through the interior of the sponge, and were seen flowing in every direction. During the maintenance of this action in full force, when I directed my observation to the osculum, it was pouring forth a continuous stream of water, and along with it masses of flocculent matter, and many of the larger molecules of the indigo that had entered by the pores; but it is remarkable that although the finer molecules of indigo were being imbibed by the pores in very considerable numbers, very few indeed of them were ejected from the osculum; and if the imbibition of the molecules continue for half an hour or an hour, and then cease, the sponge is seen to be very strongly tinted with the blue colour of the indigo, and it remains so for twelve or eighteen hours, after which period it resumes its pellucid appearance, the whole of the imbibed molecules having undergone digestion in the sarcode lining the interior of the sponge, and the effete matter having been ejected through the osculum." If we kill the sponge immediately after being thus fed, and examine the interstitial canals and cavities, we find their sarcodous surfaces thickly dotted with molecules of indigo.

The fæcal matters discharged by the oscula exhibit all the characteristics of having undergone a complete digestion; whatever may have been the condition of molecules of organized matter when they entered the sponge, their appearance after their ejection is always that of a state of thorough exhaustion and collapse.

It is difficult to decide with any degree of certainty what is really the nature of the nutriment of the Spongiadæ, but in the greater number of species it is probably molecules of both animal and vegetable bodies, either living or derived from decomposition. This appears to be the case with the greater number of the Halichondroid sponges; but even among them, as well as other genera, there are peculiarities of structure that are strongly suggestive of carnivorous habits. Thus in the first portion of this paper published in the 'Philosophical Transactions' for 1858, p. 293, I have described among the interior defensive spicula a remarkable form, which has been hitherto found in one sponge only, the spinulo-recurvo-quaternate spiculum, which "occurs in great profusion in the cavities of the sponge, clusters of them consisting frequently of as many as twelve or fifteen radiate from the angles of the reticulations of the skeleton into the interstitial cavities of the animal." I have also described, while treating on the internal defensive spicula, the recurvo-ternate forms, the heads of which are found projecting their radii, more or less, into the interstitial cavities beneath the intermarginal ones in *Geodia* and *Pachymatisma*. The spinulo-recurvo-quaternate spicula, represented *in situ* in Fig. 292, Plate XVIII, and the recurvo-ternate ones figured *in situ* in Fig. 354, Plate XXVIII, *e, e,* are both admirably adapted to destroy the victims entangled among them.

I have for a long time entertained the idea that these elaborate and varied forms of defensive spicula, probably subserved other purposes than that of the protection of the digestive surface against the incursions of minute annelids and other predaceous creatures. They are admirably fitted to retain and make prey of any such intruders. No small animal could become entangled in the sinuosities of the

interstitial cavaties of sponges thus armed without extreme injury from the numerous points of these spicula, and every contortion arising from its struggles to escape from its painful and dangerous entanglement would contribute to its destruction, and it may then by its death and decomposition eventually become as instrumental to the sustentation of the sponge as if actually swallowed by the animal. How far this mode of nutrimentation may obtain in the physiology of these creatures it is impossible, in the present imperfect state of our knowledge of their habits, to say, but from the complex, varied, and elaborate structure of these organs, and from their evident adaptation to retain such intruders, as well as to defend the internal surfaces from injury, it is not improbable that their office extends beyond that of the mere defensive function, and that they are in fact auxiliary organs for securing nutriment for the use of the sponge. If this supposition, that the elaborately formed and ingeniously disposed recurvo-quaternate spicula combine the office of securing prey with that of defending the interstitial organs of the sponge, be correct, it may afford a clue to the organic purpose of the recurvo-ternate spicula with the exceedingly long and attenuated shafts that so frequently accompany the stout patento-ternate ones in *Geodia Barretti*. The apices of these spicula (Fig. 54, Plate II) rarely attain the height of the plane of the true connecting spicula, and their recurved radii are most frequently projected into the large interstitial spaces immediately beneath the plane of the proximal ends of the cells of the intermarginal cavities, and may thus form subsidiary defences to those organs. Although emanating from the fasciculi of the shafts of the true connecting spicula, their form, slender proportion and position evidently indicate a different office from the spicula with which they are associated, and no other purpose for them occurs to me so probable as the one I have suggested above. Or we may carry the supposition further, and believe them to be not only defensive but aggressive organs; also, like the recurvo-quaternate spicula, their office may be to retain soft annelids that have intruded themselves through the oscula into the digestive organs, to aid in the nutrimenta-

tion of the sponge; and this idea appears the more feasible, as these spicula are never observed in the intermarginal cavities, where the decomposition of animal matters would be offensive to their especial function, but always in the spaces beneath them, which are the commencements of the digestive system.

The same course of reasoning will apply to their occurrence in such considerable quantities amidst the defensive fasciculi of spicula projected from the surface of *Tethea simillima*, Bowerbank, MS., and also of *T. crania*, the latter being represented by Fig. 362, *c, c*, Plate XXXI, in which it will be seen that the recurvo-ternate heads of the spicula are always situated beneath the level of the true defensive spicula. Thus situated they would form an admirable trap for the entanglement of soft annelids that might attempt to crawl over the surface of the sponge, and thus they would be destroyed and retained for the imbibition of their particles liberated by their gradual decomposition. If this be not their especial purpose in this situation, I must confess myself at a loss to imagine their proper function, as the surface of the sponge is effectually protected by the porrecto-ternate and large acuate spicula that compose the defensive fasciculi projecting in such abundance from all parts of the sponge. If we also consider the structure and positions of the ordinary forms of internal defensive spicula, the entirely spined attenuato-acuate ones, in reference to the idea of their being offensive as well as defensive organs, we shall not fail to see that, although less striking in their forms and modes of disposition than the spicula already described, they are calculated to subserve the office of retaining prey quite as effectually as the more singular ones. The abundance in which they occur, the vast number of spines with which they are covered, the apices of which are frequently long and recurved, combined with the mode in which their bases are attached to the fibres of the skeleton, exhibiting a beautiful combination of strength and flexibility, are strongly indicative of a purpose beyond that of mere repulsion.

In the two species of sponges in which are found the

acuate entirely and verticillately spined defensive spicula *in situ*, represented by Figs. 289, 290, Plate XVII, one of them has the spicula collected in groups in a manner very similar to those of the spinulo-recurvo-quaternate form, and if the latter be considered as organs for the retention of prey, the physiological purpose of the grouping together of the former can scarcely be considered in any other light.

In the isolated positions of these forms of spicula, viewed in reference to some ideas regarding their physiological purposes, there are circumstances of a very remarkable nature. These forms of spicula occur in several distinct genera of sponges, and especially in those having a strong kerato-fibrous skeleton. Their usual locality is on the fibre of the skeleton, in which their bases are firmly imbedded, and from which they are projected at various angles into the canals and cavities of the sponge, and they are very rarely seen on the membranes. In *Hymeraphia stellifera* (Fig. 370, *a*, Plate XXXIV) and *H. clavata*, Bowerbank, both exceedingly thin coating species, they occur in great quantity, but only on the basal membrane; a portion of them being erect, the remainder prostrate. But in another sponge, a remarkably curious parasitical species, *Hymeniacidon Cliftoni*, Bowerbank, MS. (Fig. 291, Plate XVII), which having no fibrous skeleton of its own, covers and appropriates a small fibrous *Fucus*, and converts its anastomosing vegetable stalks into an artificial skeleton, closely coating each stalk of the plant with its membranous structure, so as to cause them at first sight to be readily mistaken for keratose sponge fibre. The whole of the membranous structure of this sponge abounds with attenuato-cylindrical entirely spined defensive spicula, but they are all prostrate and intermingled with the skeleton spicula of the sponge when not in contact with any part of the fibres of the vegetable, but wherever they are in contact with the plant they instinctively, as it were, assume the erect position, and the false skeleton is bristling with them to as great an extent as if it were truly a kerato-fibrous structure. This feature in the habit of the sponge is very

remarkable, and highly suggestive of a capability of adaptation to circumstances that we should scarcely have expected to find. By the two instinctive habits,—first, that of converting the plant into an artificial skeleton, and then erecting its spinous spicula on its fibres,—it at once simulates the habits of a kerato-fibrous sponge, and becomes capable of the carnivorous habits that I have attributed to those sponges that are so strikingly adapted for preying on intruding annelids or other such small creatures. In the species above described, *Hymeniacidon Cliftoni*, Bowerbank, MS., the erection of the spicula on the adopted skeleton is an established habit; and it may be said to be instinctive in the species, but I have observed the same fact in sponges not habitually parasitical. I have a specimen of *Microciona carnosa*, Bowerbank, a British species, in my possession in which some small fibres of a tubular zoophyte have been accidentally included during its growth, and which the sponge has coated with its own tissues, and from these adopted columns defensive spicula are projected in a similar manner to those of the columnar skeleton of the sponge. In this case we have an instinctive adaptation of an extraneous substance in a sponge in which the introduction of foreign substances is the exception, and not, as in other tribes of sponges, the rule.

In *Hyalonema mirabilis*, Gray, a sponge nearly related to the genus *Alcyoncellum*, we find another extraordinary series of internal defensive spicula, the structure of which I have described at length under the head of "Defensive Organs." These elaborately and wonderfully-formed weapons are evidently destined for other purposes than that of simple repulsion. The spiculated cruciform spicula, with their short stout basal radii planted firmly on the lines of the skeleton, and projecting from their centre at right angles to their own plane; the long spiculated ray furnished with numerous strong sharp recurved spines, it will be at once seen, is eminently fitted to retain annelids or other such prey, and to cause every motion of the struggling victim to contribute to its own laceration and destruction, while the structure and mode of attachment of the cruciform base is

admirably calculated to resist the force and motions it has to sustain in such encounters. But these spicula, although exceedingly numerous, are not the only organs capable of retaining intruders into the body of the sponge with which it is furnished, there is in addition numerous large multi-hamate birotulate spicula dispersed in various positions on the sides of the interstitial cavities of the sponge, each of the rotulæ consisting of seven or eight stout recurved flattened radii, which, if immersed in any struggling animal, would be capable of sustaining a vastly greater amount of force than many of the spiculated quadriradiate ones combined, could endure without injury; and that their especial office is that of auxiliary retentive organs, is well demonstrated by the fact that the trenchant edges of the flattened radii are all at right angles to the line of force required to tear away their hold of any body in which they may have been inserted. Thus they appear destined by nature to secure the prey while its own struggles among the lacerating organs contributes to its destruction (Figs. 294, 295, Plate XVIII, and Fig. 60, Plate III).

In the modification of the structure of the contort biha-mate spicula, and their peculiar adaptation to the retention and destruction of intruders within the sponge, which I have described when treating on the internal defensive spicula, and which is represented in Fig. 293, Plate XVIII, and Fig. 112, Plate V, we have precisely the same physiological principle carried out, but by means widely different from those I have previously described.

If we consider the whole of these extraordinary organs to which I have referred in relation to each other, we cannot fail to see that, however varied their forms may be, there is every appearance of perfect harmony of design in the purposes they are destined to effect in the economy of the Spongiadæ.

THE CILIA AND CILIARY ACTION.

Our knowledge of the cilia of the Spongiadæ is, comparatively speaking, very small. Dr. Grant is, I believe, the first author who has seen and described these organs *in situ*. This learned and accurate observer, in his paper ‘Observations on the Structure and Functions of the Sponge,’ has described the origin and gradual development of the ova or gemmules of *Spongia panicea* (*Halichondria incrustans*, Johnston). After the liberation of these bodies from the sponge, he writes, "The most remarkable appearance exhibited by these ova, is their continuing to swim about by their own spontaneous motions for two or three days after their detachment from the parent, when they are placed separately in vessels of sea-water, at perfect rest. During their progressive motions they always carry their rounded broad extremity forward, and when we examine them under a powerful microscope, we perceive that these motions are produced by the rapid vibration of cilia, which completely cover over the anterior two thirds of their surface." And he further states that they are "longest and exhibit the most distinct motions on the anterior part," and that they "are very minute transparent filaments, broadest at their base, and tapering to invisible points at their free extremities; they have no perceptible order of succession in their motions, nor are they synchronous, but strike the water by constantly and rapidly extending and inflecting themselves." The author describes the attachment and spreading out into a thin disk of the ovum or gemmule, and the cessation of action and gradual disappearance of the cilia; and he further observes, "although all visible cilia have ceased to move, we still perceive a clear space round the ovum, and a halo of accumulated sediment at a little distance from the margin." This observation is important, as tending to prove the existence of ciliary action, although the organs themselves were too minute to be detected.

Dujardin, in his work on the Infusoria, in Plate III, 19, *b*,

represents what are apparently the detached cilia and their basal cells, and which were probably from *Grantia compressa*.

If portions of a living sponge of this species be torn into small pieces, and placed in a cell in sea-water under a power of about 400 linear, groups of the detached cilia and their basal cells will be readily seen at the margins of the specimen; they are usually thus clustered together, and have a tremulous and indistinct motion. If a small specimen of the sponge be slit open and placed in a cell with fresh sea-water, with the inner surface of the sponge towards the eye so as to command a distinct view of the oscula, the cilia will be seen in the area of that organ in rapid motion, and the extraneous molecules attached to them exhibit the extent and nature of their oscillations very distinctly (Fig. 313, Plate XXI). If the sponge be carefully torn asunder in a line at right angles to its long axis, and the torn surface be placed in a cell with a little fresh sea-water, we occasionally obtain a favorable longitudinal section of some of the large cells of the sponge, and we then see the cilia *in situ* and in motion (Fig. 312, Plate XXI).

The whole length of the cell, from the inner edge of the diaphragm to its origin near the outer surface of the sponge, is covered with tessellated nucleated cells, which have each a long attenuated and very slender cilium at its outer end. They are oval in form, and have a distinct nucleus. When in vigorous condition their motions are rapid and cannot readily be followed, but in some in which the action was languid, the upper portion of the cilium was thrown gently backward towards the surface of the sponge, and then lashed briskly forward towards the osculum, and this action was steadily and regularly repeated. Their motions are not synchronous, each evidently acts independently of the others (Figs. 314, *a*, *b*, Plate XXI).

The numbers, situation, and peculiarities of their actions fully account for the continuous and powerful stream that issues from the great cloacal aperture of this and other similarly constructed sponges. The natural rate of the motions of these organs must not be estimated from the sections last described, but the estimate must be made

from the appearances manifested at the oscular orifices at the inner surface of the sponge; a more detailed account of these investigations is published in the 'Transactions of the Microscopical Society of London,' vol. iii, p. 137. Fig. 312, Plate XXI, represents a longitudinal section of the intermarginal cavities of *Grantia compressa* with the cilia *in situ*. Fig. 313, a view of the small portion of the inner surface of the sponge, exhibiting the oscular orifices and the appearance of the cilia in motion within them, and detached cilia and cells from the same sponge.

In the course of my endeavours to detect the cilia in Halichondroid sponges, I have frequently observed in slices of the sponge taken from the surface, that the incurrent action has continued for a considerable period, while in sections of the same sponge taken from deep amid the tissues, no such action of the currents could be detected. In sections from the surface in which the inhaling process was in vigorous condition, when the inside of the section was examined, that peculiar flickering appearance was often visible in the cavities immediately beneath the dermal membrane, which is so characteristic of minute cilia in very rapid motion; and although many molecules were rushing inward with considerable velocity, others might be seen which continually waved from side to side but made no progress forward; in fact they presented precisely the appearance that I have described as taking place in the oscula of the proximal ends of the great intermarginal cells of *Grantia compressa;* and I have no doubt, in my own mind, that those of the Halichondroid sponges were also extraneous particles of matter adhering to the apices of the minute cilia, rendering their motions apparent, while the cilia themselves were perfectly invisible.

Carter, in his paper on "Zoosperms in *Spongilla*," published in the 'Annals and Mag. Nat. Hist.,' vol. xiv, Second series, p. 334, describes ciliated bodies from a *Spongilla* from the water-tanks of Bombay, somewhat similar to those of *Grantia compressa*, but the basal cell appears to be larger and the cilium shorter in their proportions than those of *G. compressa*. The author, in

describing the detached cells and cilia, says, "At first the polymorphism of the cell and movements of the tail are so rapid, that literally, neither 'head nor tail' can be made out of the little mass. Presently, however, its power of progression and motion begins to fail, and if separated from other fragments it soon becomes stationary, and after a little polymorphism assumes its natural passive form, which is that of a spherical cell. During this time the motions of the tail become more and more languid, and at length cease altogether." The author continues, "If on the other hand, there be very large fragments in the immediate neighbourhood, or an active sponge-cell under polymorphism sweeps over the field, it may attach itself to one or the other of these, when its cell becomes undistinguishable from the common mass, and the tail floating and undulating outwards is all that remains visible." This observation is important, as it accounts in a great measure for our inability to find the cilia *in situ* in the living and active condition of the *Spongilla;* and if the structure and imbedment of the basal cell in the marine sponges be like those in that genus, the same results would probably arise in the marine species, rendering it extremely difficult, if not impossible, to detect these organs *in situ* and in action.

Lieberkuhn, in his paper in Müller's 'Archiv,' 1856, pp. 1-19, 319-414, gives an account of the cilia and their cells *in situ.* He describes them as forming a single layer of spherical cells, $\frac{1}{300}$ millim. in diameter, and which, though touching each other, are not in such contact as to lose their rounded figure. Lieberkuhn's description of the mode of disposition of these cells in *Spongilla* would serve equally well for those in *Grantia compressa.* Professor Huxley, in a paper "On the Anatomy of the Genus *Tethya,*" published in the 'Annals and Mag. Nat. Hist.,' vol. vii, p. 370, describes cells and cilia from an Australian sponge, which he designates spermatozoa, and which he describes as having "long pointed, somewhat triangular heads, about $\frac{1}{300}$th of an inch in diameter, with truncated bases, from which a very long filiform tail proceeds." These bodies are figured in Plate XIV, vol. vii, fig. 9.

On a careful consideration of the descriptions of the ciliated cells seen by the authors I have quoted above, it strikes me forcibly that the so-called zoosperms and spermatozoa of Carter and Huxley are identical in origin and purpose with the similar organs described by Lieberkuhn, and those found *in situ* and in action in *Grantia compressa*, and in truth that they are the homologues of the breathing and feeding organs of the zoophytes and more highly organized animals.

REPRODUCTION.

The ovaria in sponges exhibit considerable variety in shape and structure. The most familiar form is that of *Spongilla fluviatilis*, represented in Fig. 317, Plate XXII, in its natural condition.

These bodies have hitherto been usually designated as gemmules, but this term appears to be inappropriate. Each of them contains numerous minute vesicular, round or oval molecules, which are discharged from the foramen in succession, and each of these appears to be capable of producing a sponge. The terms ovarium and ova are therefore more in accordance with the rules of modern nomenclature, and this alteration in their designation is the more necessary, as I shall hereafter be enabled to show that in *Tethea lyncurium* propagation by true external gemmatian in that species at least really exists. I propose, therefore, for the future that all such large vesicular organs containing numerous molecules or ova capable of reproducing the species, and of being successively ejected from the sponge, should be designated ovaria and ova, and that the term gemmule should be restricted to the isolated bodies which pullulate from the internal or external surfaces of the parent, and by ultimate separation become each a distinct individual.

The reproductive powers of the Spongiadæ have been treated on to a considerable extent by preceding authors, and the amount of our information on this subject is, I

believe, both extensive and accurate. I will not attempt a recapitulation of all that has been written on their reproduction, but content myself with a slight sketch of our knowledge of the various modes of propagation that have been well ascertained and described. From the researches of the various authors who have written on the structure and development of *Spongilla* and on the marine Spongiadæ, it appears that there are three well-established modes of propagation: 1st, by ova; 2nd, by gemmation; and 3rd, by spontaneous division of the sarcode. The terms ova and gemmule have been used so indiscriminately by authors, that it seems to me advisable to endeavour to define and limit their application in such a manner as to distinctly separate the one form of reproductive body from the other.

On a careful review of the results of the labours of previous observers and of my own researches, it appears that the following may be considered as the varieties that exist in the modes of the propagation of the Spongiadæ:—

1st. By ova without an ovarium.
2nd. By ova generated within ovaria.
3rd. By gemmules secreted within the sponge.
4th. By gemmules produced externally.
5th. By spontaneous division of the sarcode.

On the first mode of propagation by the means of ova generated in the sponge without the presence of ovaria, very little seems to be known, and this mode appears to be confined to the true sponges, the genus *Spongia*. If we examine microscopically the fibres of the sponges of commerce in the condition in which they come into the hands of the dealers, and before they have been soaked, cleaned, and prepared for sale, we frequently find the fibres covered with innumerable minute irregularly ovoid vesicular bodies nearly uniform in size, dispersed evenly over the surface of the fibres, and imbedded in a thin stratum of sarcode that coats the membranous sheath that surrounds them. These bodies Dr. Johnston believes to be "the matured gemmules or sporules," and I feel strongly inclined to agree with him in the conclusion that they are the reproductive bodies of

that tribe of sponges, and no other reproductive bodies have, I believe, been discovered in the true sponges; but in arriving at this conclusion, we must not fail to remember that our knowledge of these animals in the fleshy and solid condition in which they are when alive, is so limited and so few observations have been published regarding them in that state, that we must not attach too great a value to these conclusions.

In size and form these ovoid vesicles are very similar to the ova liberated from the well-characterised ovaria of other marine species of Spongiadæ; and like them, they present no appearance of a nucleus. They are somewhat irregular in their form, and vary to a slight extent in size; an averaged-sized one measured $\frac{1}{11666}$th of an inch in diameter. Fig. 315, Plate XXII, represents a portion of a fibre from a Bahama sponge under a power of 400 linear, and Fig. 316, a part of the same fibre 1250 linear.

Until very recently our knowledge of the vesicular ovaria of the Spongillidæ has been confined to two European species, but Carter, in his excellent account of the *Spongillas* found in the water-tanks of Bombay, has described several new and interesting varieties of these organs; and I have also become acquainted with eight new species from the River Amazon, through the kindness of Mr. Bate, and of three undescribed species from North America, through the kind and liberal assistance of Dr. Asa Gray, Professor Leidey and Professor Dawson, of McGill College, Montreal, Canada. The greater portion of these organs resemble each other very closely in their natural condition, presenting generally the appearance of a more or less spherical coriaceous body, but the structure of their walls, when developed by treating them carefully with hot nitric acid, is so varied and strikingly characteristic of their organic and specific differences, as to render it necessary that I should enter somewhat minutely into their history. Their structual peculiarities naturally divide them into two great groups.

1st. Those in which the walls of the ovaria are strengthened and supported by birotulate or unirotulate spicula radiating in lines from the centre to the circumference of

the ovarium; and 2nd, those having the walls of the ovaria supported by elongate forms of spicula, disposed on or near its surface at right angles to lines radiating from the centre to the circumference of the ovarium; and fortunately the types of these two forms of spicular arrangement on the cortex of the ovarium are admirably illustrated in the two European species of *Spongilla*; the first mode existing in *Spongilla fluviatilis*, and the second one in *S. lacustris*. After having described the ovaria of these two species as types of their respective groups, I shall in my future descriptions of these organs confine my observations rather to their anatomical structure than to their external characters, excepting when the latter are of an unusual description. These bodies occur in great profusion in the basal portions of *S. fluviatilis*; they are spherical and of an average diameter of $\frac{1}{80}$th of an inch, and they are furnished with a circular foramen at their distal extremity of about $\frac{1}{833}$rd of an inch in diameter. In their natural condition they exhibit very slight indications of the birotulate spicula imbedded in their coriaceous-looking envelope. In the dried state they become cup-shaped by the contraction of the upper half inward during the process of desiccation, and in this condition the foramen appears at the bottom of the cup. The edges of the cup being thick and round in consequence of the presence of the birotulate spicula beneath the fold of the membrane, and the surface becomes pitted with numerous minute lacunæ, which are produced by the adhesion of the inner surface of the envelope to the distal extremities of the birotulate spicula. Immersion in water for an hour restores them to their spherical form, but does not obliterate the lacunæ produced by desiccation; and I have several times observed that, under these circumstances, the expansion of the ova within has forced one or more of them through the foramen.

If we take several of the ovaria, either in the living condition or in the expanded state I have described above, and place them in a test-tube with a little nitric acid, and raise the temperature of the whole until the ovaria becomes of a bright yellow colour and semi-transparent, and then arrest

the operation of the acid by immediately pouring in a quantity of cold water, we shall have preserved their form and have retained the spicula in their natural positions, and have rendered the whole so transparent, as to exhibit their form and arrangement in the walls of the ovarium, either in water or mounted in Canada balsam, in a very beautiful and satisfactory manner. They are packed very closely together, their shafts being in lines radiating from the centre of the ovarium to the circumference; their distal rotulæ supporting the outer surface of its wall, while the proximal rotulæ sustain the inner one. Fig. 319, Plate XXII, represents a portion of one of these prepared ovaria, and Fig. 319, *a*, one of the detached spicula. Two views of this form of spiculum are also represented in Figs. 217, 218, Plate IX, and a perfect ovarium prepared by acid by Fig. 318, Plate XXII.

Carter, in his paper "On the Freshwater Sponges in the Island of Bombay," in describing the birotulate spicula of the ovaria of *Spongilla Meyeni* and *plumosa*, species with ovaries of very similar structure to those of *S. fluviatilis*, states that the spaces between the rotulæ are "filled up with a white siliceous amorphous matter which keeps them in position." I am indebted to the kindness and liberality of the author for specimens of these species, and I have frequently subjected their ovaries to the action of hot nitric acid, but I have never succeeded in finding any intervening siliceous matter, nor have I ever found any such siliceous cementing material in any other similarly constructed ovary of a *Spongilla*.

In the second group of ovaries of the Spongillidæ, represented by those of *S. lacustris*, in which the walls of the ovaria are supported by elongate forms of spicula disposed at right angles to lines radiating from its centre, the ovaria, in their natural condition, exhibit but very slight traces of the spicula imbedded in their walls. When dried they cup inward like those of *S. lacustris;* but the margin of the cup is thin and sharp compared with that formed in a similar manner by those of *S. fluviatilis*, and they expand also in like manner when immersed in water. When

treated with hot nitric acid they display an abundance of short, stout, entirely spined subarcuate acerate spicula, one of which is represented in Fig. 203, Plate IX. These spicula are in many instances exceedingly numerous; they are disposed without order, and overlie each other at various angles, forming, in their imbedment in the envelope, a strong and very efficient irregular network of spicula. A portion of one of these prepared ovaria is represented in Fig. 320, Plate XXII.

In the ovaries of the different species of *Spongilla*, to be arranged hereafter in accordance with these structural peculiarities, there is a considerable amount of general resemblance, but accompanied with such permanent variations in the structure of the spicula, and in other portions of the development of these organs, as to render a somewhat detailed description of them necessary. Thus in the development of the birotulate spicula, the ovaries of *Spongilla plumosa*, Carter, exceed any other known species. The thick walls of these organs are filled with them in the state represented by Fig. 208, Plate IX, and the intervals between their shafts appear to be filled with indurated sarcode or keratode. In *Spongilla Meyeni*, Carter, the structure of the walls of the ovaria are strikingly similar to those of *S. fluviatilis*, and the form of the spicula the same, with the exception of the shafts being very much more spinous, and the size of the spiculum twice that of *S. fluviatilis*. Fig. 219, Plate IX, represents a spiculum from an ovary of *S. Meyeni*. The smallest and most simple development of birotulate spicula exists in *Spongilla gregaria*, Bowerbank, from the River Amazon, represented by Figs. 213, 214, 215, and 216, Plate IX.

A gradual transition from the birotulate form to that of the unirotulate one takes place in the ovaries of *S. paulula* (Fig. 221) and *S. reticulata* (Fig. 223), until we obtain the perfect and beautiful unirotulate form in the ovaries of *S. recurvata*, represented by Figs. 224 and 225 in the Plate quoted above. In all these species there is a general accordance in the mode of their structure.

The gradual transition from the birotulate to the uniro-

tulate form of spiculum in the ovaries of *Spongilla reticulata* is not the only characteristic difference that exists between it and its congener. The form and structure of the ovarium also exhibit markèd peculiarities of character, and it is also furnished with a beautiful reticulated spicular envelope or case. In its natural condition the ovary fills the reticulated case, and the coriaceous external surface is pressed into the areas of the network.

It is usually oviform, but it varies to some extent in its shape. When treated carefully with hot nitric acid, the outer coriaceous substance of the ovarium is dissolved, leaving the inner membrane and the boletiform spicula *in situ;* their larger terminations being applied to the distal surface of the membrane, while their smaller clavate or stellate ends are projected outward, reaching, in the natural condition, to very near the external surface of the ovarium. The foramen is situated at the small or distal end of the ovary, and differs from that of any other form of the organ with which I am acquainted, inasmuch as it exhibits a tubular elongation outward of the lining membrane equal in length to about its own diameter, causing the ovarium, when prepared with nitric acid, to appear like an oil-flask with a very short neck. Fig. 323, Plate XXIII, represents one of the ovaria prepared with acid, and Fig. 322 one of the cases in which they are contained.

In *Spongilla Brownii*, Bowerbank, there is a still further deviation in the structure of the spicula of the ovary. The shaft entirely disappears, and the spiculum is reduced to the umbonato-scutulate form. They are situated on the outer surface of the inner membrane of the ovarium, with the umbones of the scutellæ outwards. This mode of disposition obviously renders them inefficient for external defence, and the ovaries have therefore been further defended by being inclosed within an elaborately constructed case of reticulated acerate spicula. The ovary is closely embraced by this envelope, and small elongate masses of its outer surface are projected through some of its interstices, causing it to be more or less tuberculous; and, from the smallness of the interstices, the tubercles of the envelope of

the ovary are much greater in length than in thickness. The spicula of the case are disposed in a close and irregular network, seldom exceeding two spicula in thickness. By a careful treatment with hot nitric acid, the thick coriaceous outer portion of the ovarium may be removed, and its thin lining membrane, with its stratum of umbonato-scutulate spicula, becomes an exceedingly beautiful object. The same mode of operation displays the structure of the reticulated case of the ovary very much more distinctly than when viewed in its natural condition. Fig. 321, Plate XXII, represents two of the cases after treatment with acid, one of them (*b*) having the ovary very much reduced in size by the dissolution of the thick coriaceous portion of its structure.

In the second group of the ovaries of the Spongillidæ there is also a strong general resemblance in structure to the type-form of *S. lacustris*, but each species is distinctly characterised by peculiarities of form and arrangement of the spicula.

The normal form is spherical, and the walls of the ovaries, in six out of the seven species with which I am acquainted, are comparatively thin. In the seventh species, *S. Carteri*, Bowerbank (*S. friabilis*, Carter), they are very thick and abundantly furnished with cellular structure, arranged in lines radiating from the centre to the circumference; each line consists of nine or ten cells, the length of each being about equal to the diameter. They are very closely packed together, and are irregularly angular by compression. Their combined length varies from about one-fifth to one-sixth the length of the diameter of the ovarium. This is the only species in which I have detected this description of cellular structure. Fig. 284, Plate XVI, represents a portion of the surface and a view of the cells *in situ*.

Although the spiculated coriaceous form of ovarium prevails so constantly among the freshwater sponges, it is one of extremely rare occurrence among the marine species; and I have met with only one instance of its occurrence, and that is in a new genus of sponges from Shetland, for which I am indebted to my late indefatigable friend Mr. Barlee. The specimen incrusts a portion of the valve of a *Pecten*,

covering a space about half an inch in length and the eighth of an inch in breadth, and it does not exceed half a line in thickness. The ovaries are numerous and closely packed together, and are distinctly visible to the unassisted eye, looking like very minute cocoons of some terrestrial insect. There were nearly thirty in an area equal to about a quarter of an inch. They are attached by the sides to one or more branches of the fibrous portion of the skeleton.

The wall of the ovary is very thin, and appears to consist of a single membrane profusely furnished with acerate spicula, like those of the skeleton. They cross each other in every possible direction, and occasionally appear to assume a somewhat fasciculated arrangement. The ovaries are not uniform in shape, some being regularly oval, while others are more or less ovoid. I could not detect any trace of a foramen in those I subjected to examination. I have designated this interesting species *Diplodemia vesicula* in my description of it. Fig. 324, Plate XXIII, represents two of the ovaries in their natural condition after immersion in Canada balsam, magnified 83 linear.

In the genera *Geodia* and *Pachymatisma* ovaria are produced in great abundance. They agree in form very closely with those of *Spongilla*, but their structure is widely different, and the soft animal matter that enters so largely into the structure of those of the freshwater sponges scarcely makes its appearance in the ovaries of *Geodia*, their walls being composed of closely packed spicula, firmly cemented together by silex. Their situation in the animal is also different from those of *Spongilla*, in which they are dispersed amid the interstitial tissues, but principally towards the base of the sponge, while in *Geodia* and *Pachymatisma* they are congregated in large quantities immediately beneath the dermal membrane; and when they have shed their ova they permanently retain their situation, forming a thick crustular dermis for the protection of the softer portions beneath: a few only are found dispersed in the interstitial membranes of the sponge. The progressive development of this kind of ovarium is very nearly the same in every species of *Geodia* or *Pachymatisma* in which I have had an opportunity of

examining them. In an early stage they appear as a globular body of fusiformi-acerate spicula, radiating regularly from a central point in the mass. As the individual spicula increase in diameter there is a corresponding distension of the ovarium, and as the spicula do not lengthen in proportion to their increase of diameter a central cavity is produced, in which the incipient ova very shortly appear. The spicula of the wall of the ovary continue to increase considerably in diameter, but very little in length, and their distal terminations become gradually less acute as they approach the period of the full development of the ovary. When this organ has attained its greatest diameter, their distal extremities cease to lengthen, and a gradual change in the form of the spicula is effected, their apices extending in diameter and assuming a truncated form, and the whole of them becoming firmly cemented together, so as to form a common flat smooth surface to the siliceous skeleton of the ovarium, each spiculum having now changed from the acerate to the acuate form, their proximal acute terminations forming the common inner surface of the cavity of the ovarium, which is now filled with an opaque mass of ova. A single conical orifice or foramen has also been produced in a portion of the wall, through which the ova are destined to be ejected. The proximal end of this foramen is very much the smaller of the two, so that, as soon as an ovum has fairly entered this conical tube, there is no longer any impediment to its ejection: and the manner in which this is effected is very interesting, and appears to be as follows. When the ova have attained maturity, the proximal terminations of the spicula which have not been cemented together like their distal ones, are progressively and simultaneously lengthened, thereby encroaching on and gradually lessening the diameter of the cavity within, so that the ova are compressed and forced through the foramen; and this process appears to be continued until the whole of them have been ejected, and the cavity becomes completely filled by the continued encroachment of the proximal ends of the spicula of the walls of the ovarium.

In Fig. 327, Plate XXIII, two ovaries from *Geodia*

McAndrewii containing ova are represented: (*a*) contains about the greatest quantity of ova that is found within these organs. In this one the distal terminations of the spicula of the skeleton are still somewhat rounded, and slightly elevated above the common surface; while in (*b*), which has been partially exhausted of the ova, the spicula have their distal terminations flat and somewhat angular, and they are level with the general surface, thus indicating a greater age and a fuller development than obtain in the one represented by (*a*), and not a less amount of secretion of ova, as might possibly be imagined. These circumstances are strongly indicative of the fact that the ovaria, both in an active and effete state, are permanently seated in the sponge, and that the ova only are discharged from it. So in like manner the existence of the ovarium in *Spongilla reticulata* and *Brownii*, Bowerbank, confined within a strong spicula case firmly incorporated with the skeleton, is strong presumptive evidence of their also being permanent organs, and not of the nature of gemmules which separate from the body of the sponge when they arrive at maturity and are ejected through the great fæcal orifice.

Many other species of *Geodia* with which I am acquainted afford these ovaria in great abundance, and with some variations in size and form from those in *G. McAndrewii*, Bowerbank, MS., but in no other sponge are they so large and so completely developed.

Fig. 325, Plate XXIII, represents an adult ovarium from *Geodia McAndrewii* with the conical foramen on its summit, and the distal ends of the skeleton spicula flat and angular. Fig. 326 represents a small portion of the surface of the same specimen as seen with a linear power of 308, exhibiting the flatness and angularity of their distal apices. Fig. 329, Plate XXIV, represents a portion of a young ovarium having the distal ends of the skeleton spicula disunited and acutely conical. Fig. 328, Plate XXIII, represents a portion of a section of an ovarium of *G. McAndrewii*, exhibiting the radial arrangement of its component spicula.

In *Pachymatisma Johnstonia*, Bowerbank, a British

species common on the rocks in the neighbourhood of Torquay, and which I described in a paper read before the Microscopical Society of London in 1841, these organs assume an oval form; they are also considerably depressed. In a young specimen of this species of sponge in my possession, the progressive development of the ovaria is very strikingly illustrated. Fig. 330, Plate XXIV, represents an adult ovarium. Fig. 331, one in a semideveloped state, and Fig. 332, one of the same organs in a very early stage of development. In another species of sponge from the South Seas we find a singular variety of this class of ovarium. It is oval in form, the length being to the breadth as five to three, but it is so much depressed as to appear rather like a dermal spicular plate than an ovarium; but the radiate arrangement of its component spicula is perfectly visible with a power of 666 linear, and their distal terminations as separate and distinct as those of *Geodia* or *Pachymatisma*. The situation of the foramen is also well defined in many of them. Fig. 333, Plate XXIV, represents a mature ovarium; Fig. 334, a fragment of one to exhibit its degree of thickness; and Fig. 335 represents one of the same species of ovarium in an early stage of development. I have seen four species of sponge which have this description of ovarium; in one it is very considerably longer in its proportions than that represented by Fig. 333, Plate XXIV, and in another species it is somewhat shorter.

Since the preceding portion of the account of the ovaria was written I have received a very remarkable specimen of these organs, which differs materially in its structure from any of the forms that I have previously described. The sponge consists of a small portion of basal membrane, closely resembling that of a Halichondraceous species. It was found by my friend Mr. J. Yate Johnson coating rocks and stones at Madeira. The remains of several exhausted ovaria are dispersed over the surface of the membrane, a few only retaining their original form and proportions. They do not appear to have had a spicular skeleton, but to have consisted of a coriaceous envelope strengthened and supported by a reticulated skeleton of apparently keratose

structure. They are nearly globular, and are firmly cemented to the membrane by a broad basal attachment. Although themselves apparently in an effete state, the membrane on which they are seated was in a decidedly living and active condition. It is thickly coated with sarcode, and abundantly furnished with equi-anchorate spicula. Numerous slender acuate or subspinulate spicula are also dispersed over its surface, which are occasionally fasciculated after the manner of the first indications of the formation of a Halichondraceous skeleton. But the most interesting feature of the membrane is, that at intervals over the whole of its surface, and especially at those parts most free from the dispersed spicula, there are small detached groups of spicula, each consisting of two or three irregular fasciculi crossing each other at various angles, resembling in every respect the early stages of development of the gemmules or ova so graphically described by Dr. Grant in his account of the gemmules of the sponge he has designated *Halichondria panicea*.* The presence of these early developments of the ova is precisely in accordance with the discharged and effete condition of the ovaries, and is just such an effect as might naturally be expected under such circumstances. Fig. 336, Plate XXIV, represents one of these ovaria seen by a microscopic power of 108 linear; Fig. 337, a small piece of the reticulated wall of the ovarium with a power of 308 linear; and Fig. 338 represents the development of one of the ova and the surrounding equi-anchorate spicula with a power of 108 linear.

Gemmules.

If we adopt as a definition that a gemmule is a body not containing ova, but that it is a vital mass separated from the parent and capable of being ultimately developed into a single individual possessing the same specific characters

* 'Edinburgh New Philosophical Journal,' vol. i, p. 16, plate ii, figs. 24—29.

and capabilities as the parent mass, we must consider the reproductive bodies so ably and minutely described by Dr. Grant in his paper "Observations on the Structure and Functions of the Sponge,"* not under the designation of ova, but rather under that of gemmules; and indeed the learned author seems to have entertained some doubt of their being correctly designated by the former term, as in speaking of them in a subsequent portion of his paper in page 14, he says, "since these germs or so-named ova are, &c.;" I have therefore been induced to arrange them under the designation of Gemmules.

Dr. Grant describes their first appearance in the sponge in the months of October and November "as opaque yellow spots visible to the naked eye, and without any definite form, size, or distribution, excepting that they are most abundant in the deeper parts of the sponge and are seldom observable at the surface;" he also states that "they have no cell or capsule, and appear to enlarge by the mere juxtaposition of the monad-like bodies around them. As they enlarge in size they become oval-shaped, and at length in their mature state they acquire a regular ovate form." When they have attained a fully-developed condition, they separate from their attachment to the parent and pass out of the fæcal orifices. At this period of their existence the learned author states that they are endowed with spontaneous motion, in consequence of their larger extremity being furnished abundantly with cilia, which the author describes as "very minute transparent filaments, broadest at their base, and tapering to invisible points at their free extremities." After floating freely about for a period, they attach themselves to some fixed body, adhering firmly to it, and spreading themselves out into "a thin transparent convex circular film." The author further states that "when two ova in the course of their spreading on the surface of a watch-glass come into contact with each other, their clear homogeneous margins unite without the least interruption, they thicken, and produce spicula: in a few days we can

* 'Edinburgh New Philosophical Journal,' vol. i, p. 16, plate ii, figs. 24-29.

detect no line of distinction between them, and they continue to grow as one ovum."

I have never had the good fortune to see the living gemmule with its cilia in action, as described by Dr. Grant; but I have frequently found Halichondraceous sponges with an abundance of these gemmules attached to their tissues; and I have in my possession a beautiful little specimen, dredged off Shetland, for which I am indebted to my kind friend Mr. Barlee, which is very illustrative of Dr. Grant's description of the mode of the development of the young sponge after the ovum or gemmule has attached itself. On a fragment of a bivalve shell there are more than twenty or thirty of Dr. Grant's ova or gemmules, which are all in the same early stage of development, each forming a small group of extremely slender spicula. The groups are separate from each other, but very closely adjoining. The diameter of one of the largest does not exceed $\frac{1}{300}$th of an inch, and their distance from each other is about half or once the diameter of one of them. In their present state, as represented by six of them in Fig. 339, Plate XXIV, it is evident that they are separate developments; and it is equally evident that a slightly further amount of extension would have caused them to merge in one comparatively large flat surface of sponge. We see by this instance that a sponge is not always developed from a single ovum or gemmule, but, on the contrary, that many ova or gemmules are often concerned in the production of one large individual; and this fact may probably account for the comparatively very few small sponges that are to be found,—a few days probably serving by this mode of simultaneous development to form the basal membrane of the sponge, of considerable magnitude, as compared with the individual ovum or gemmule, or with a sponge developed from a single ovum only. This mode of reproduction appears to have a very wide range. It is common to several distinct genera of Halichondraceous sponges; and I have observed it also in a siliceo-fibrous sponge, *Iphiteon panicea* of the Museum of the Jardin des Plantes, Paris. Fig. 340, Plate XXV, represents a small piece from the interior of the skeleton of

Iphiteon panicea. Although the latter sponge is so widely different in structure from the Halichondraceous tribes of sponges, its mode of propagation by gemmation seems to be in perfect accordance with them. In *Tethea cranium* the same mode of reproduction by gemmules obtains, but the form of the organ is different, and there are other peculiarities in its growth and development that are extremely interesting.

The form of the gemmules is regularly lenticular; and there are two distinct sorts of them, which are always grouped together. The first is rather the smaller of the two, and has a nucleus of slender curved fusiformi-acerate spicula only. The bases of the spicula cross each other at the centre of the gemmule, and the apices radiate in all directions towards the external surface, but do not, in the fully developed state of the gemmule, project beyond it. The second sort of gemmule is furnished with three distinct forms of spiculum. The first are like those of the gemmule described above, slender fusiformi-acerate; the second are attenuato-porrecto-ternate, the radii being given off from the apex at about an angle of 45 degrees; and the third form is attenuato-bihamate or unihamate, and the hooked apices of this form are projected further than either of the other two forms, but do not pass beyond the inner surface of the tough dermal envelope of the gemmule when in the adult state. I have examined a great number of these gemmules, and could never find in the form first described any indication of either ternate or hamate spicula, and I am therefore satisfied that they are separate descriptions of gemmule, and that the first form is not a transition state from the young and undeveloped to the fully developed one. In like manner I have closely observed the second form, and have always found it uniform in character, and furnished with the whole three forms of spicula that characterise it. It is highly probable that this marked difference in structure is sexual, and, from the more highly developed condition of the second or large form, that it is the female or prolific gemmule; but on this point we must at present be satisfied with conjecture only, as although I have searched

diligently for spermatozoa in both forms of gemmule and in the surrounding sarcode, I have not been able to detect anything resembling them. But that such bodies do occur in some species of *Tethea* appears to be the case, Professor Huxley having described and figured bodies which he believed to be spermatozoa in a paper published in the 'Annals and Mag. Nat. Hist.' Second Series, vol. vii, p 370, plate 14, as occurring in a species of *Tethea* found in one of the small bays in Sydney Harbour, Australia. The gemmules represented by Fig. 343, Plate XXV, consists of (*a*) one of the larger and supposed prolific gemmules, and (*b*) one of the presumed male gemmules *in situ*, × 108 linear. Wherever the former occurs, the latter appear always to accompany them in the proportion of about two or three to one. They are not seated like the ovaria of *Geodia* at the surface of the sponge, but are always found on the interstitial membranes at a considerable depth within the sponge. The immersion of the specimen in Canada balsam has rendered the marginal lines of the gemmules undistinguishable from the surrounding sarcode, but their natural boundaries would be just beyond the extreme points of the spicula.

Fig. 344, Plate XXV, represents one of the larger gemmules in its natural condition and separated from the sponge, by direct light and a linear power of 50.

The reproductive bodies in the *Tethea*, described by Professor Huxley, do not resemble those in *T. cranium*; no spicula are either described or figured as existing in them, and in these respects they appear much more to resemble the reproductive organs described by Dr. Grant as existing in the Halichondraceous sponges of the Firth of Forth. But I am not surprised at this discrepancy, as in *Tethea simillima*, Bowerbank, MS., in the collection of the Royal College of Surgeons, from the Antarctic regions of the South Sea, a species very closely resembling *T. cranium*, the gemmules are so like those of the latter species as not to be readily distinguished from them in their natural condition; but when microscopically examined, not the slightest trace could be found of the smaller, and what I con-

ceived to be the male gemmule in *T. cranium*. I have several other species of *Tethea* in my possession, but I have not yet found gemmules in the interior of any of them.

EXTERNAL GEMMULATION.

In *Tethea lyncurium* we have gemmules produced externally, which are perhaps much more entitled to that designation than any of the reproductive organs previously described. The fasciculi near the base of the *Tethea* are protruded considerably beyond the surface of the animal, and at the termination of each there appears a small mass of sarcode, which assumes a more or less globular form. If their bodies be immersed in Canada balsam and examined microscopically, they will be found to contain not only the spicula projected from the parent, but a second series, which have been secreted in the mass which have assumed the mode of disposition so characteristic of the skeleton of the parent *Tethea*. I am indebted to my late friend Mr. T. H. Stewart for this interesting fact, and for the specimens illustrating it. They were found in Plymouth Sound.

Fig. 342, Plate XXV, represents one of these gemmules with a portion of the skeleton fasciculus on which it is produced, under a linear power of 50.

PROPAGATION BY SARCODOUS DIVISION.

The fact of the resolution of the sarcode of the interstitial tissues of *Spongilla* into small masses of unequal size and variable form has long been known to naturalists, and that when separated from the parent body each becomes capable of locomotion, and of ultimately becoming developed into a perfect sponge. Carter, in his valuable paper published in the 'Journal of the Bombay branch of the Royal Asiatic Society,' No. 12, 1849, has given a minute account of their structure and motions when separated from the species which form the subjects of his paper, and his descriptions are in perfect accordance with the similar bodies separated

from our European species *S. fluviatilis*, which I have had frequent opportunities of observing, and of confirming the history given by him of their locomotive powers and continual inherent motions. The author designates these bodies "sponge-cells," and treats of them as if they had a well-defined cell-wall, while their eccentric changes of form are perfectly inconsistent with such a structure. Lieberkuhn, in treating of these bodies under the name of motile spores, states that he has never succeeded in discerning a "cell-membrane" around these particles, and my own observations are in perfect accordance with his experiences. The truth appears simply to be that any minute mass of sarcode, whether separated voluntarily or involuntarily, has inherent life and locomotive power, and is capable of ultimately developing into a perfect sponge; and in the course of this process the dermal membrane is produced at a very early period, and this, surrounding an agglomeration of minute masses of sarcode, may have been mistaken by Carter for a cell membrane. The same author, in his observations 'On the Species, Structure, and Animality of the Fresh-water Sponges in the Tanks of Bombay,' states "that when the transparent spherical capsules which contain the granules within the seed-like bodies are liberated by breaking open the latter under water in a watch-glass, their first act is to burst; this takes place after the first thirty-six hours, and their granules, which will presently be seen to be the true ova of a proteaniform infusorium, varying in diameter from about the $\frac{1}{4300}$th part of an inch to a mere point, gradually and uniformly become spread over the surface of the watch-glass. On the second or third day (for this varies) each granule will be observed to be provided with an extensible pseudo-pediform base; and the day after most of the largest may be seen slowly progressing by its aid, or gliding over the surface of the watch-glass in a globular form by means of some other locomotive organs."

This description is strikingly similar to the same author's account of the masses of sarcode separated from the sarcodous lining of the interstitial canals of *Spongilla;* but it must be observed that, in the development of the egg, the

first act is to liberate itself from the membranous envelope; and the contents thus hatched become moving masses of free sarcode, but without the locomotive cilia that are found on the so-called ova or gemmules of the marine sponges, so minutely and accurately described by Dr. Grant in his papers "On the Structure and Functions of the Sponge" in the 'Edinburgh New Philosophical Journal,' vol. ii, p. 129. This author describes the ova or gemmules of *Halichondria panicea* (*Hal. incrustans*, Johnston), after having floated freely about for a period by means of the cilia around its larger extremity, as attaching itself to a fixed body by its smaller end and then gradually settling down in the form of a broad flat mass, and after losing its cilia being gradually developed in the form of the parent sponge. Thus every description by these close and accurate observers tend to the conclusion that the multiplication of the sponge is effected by the origination in the ovum, or by the agglomeration in the form of gemmules, of particles of sarcode. The action of the minute masses of sarcode liberated by the bursting of the envelope of the ovum, and their subsequent development, is precisely that of the so-called sponge-cell liberated from the mass of the sarcode lining the interstices of the sponge, and of the gemmules described by Grant when sessile; each moves independently at first; each unites with its congeners into one body: and the results, both in means and end, are precisely the same, but their origin is different. The one is a generation of sarcode within a proper membrane in the form of an egg, while the others are the production of a gemmule by independent growth, or by spontaneous division of the sarcodous substance of the sponge.

Both these modes of propagation occur in the same species, *Spongilla fluviatilis*, but I have never yet seen them both well developed in the same individual. Where the ovaria were abundant, the sarcode appeared even and consistent in its structure, and, on the contrary, if it exhibited manifest symptoms of granulating, very few or none of the ovaria could be detected. This double means of propagation is by no means uncommon among the Zoophytes.

I have never seen the spontaneous granulation of the sarcode in any living marine species of sponge; but as the vital powers and general physiological characters of that substance appear to be the same in all the Spongiadæ, however varied in form and structure, it is highly probable that perpetuation by spontaneous or accidental separation of minute masses of sarcode is by no means confined to *Spongilla;* and from the concurrent testimony of all who have investigated the subject, that every molecule of sarcode, however minute, has inherent vitality, and the power of uniting with its own congeners whenever they may chance to come in contact.

GROWTH AND DEVELOPMENT OF SPONGES.

The growth of the sponge does not appear to be continuous, but periodical, as we may observe in the branching species, and especially in *Isodictya palmata*, Bowerbank. If the sponge be held up between the eye and a lighted candle, as many as five or six of the former pointed terminations of the sponge in succession, from near the base to the apex, may be seen; and the former lateral boundaries are also equally distinct, the oscula being most frequently, but not always, continued through the new coating of the lateral development of the spongeous structure. New branches are also frequently thrown out during the last period of development at various parts of the stem, where no indication of branches existed previously. In all these newly-developed parts, it may be observed that the primary lines of the structure of the skeleton, or those radiating at nearly right angles to the axis of the sponge, are those which are first developed; and at the extreme points of the branches they are frequently seen projecting for, comparatively, a considerable distance in the form of single unsupported threads or filaments; but as we trace these lines inward, we find the secondary, or connecting fibres increasing in number, and the network becoming closer and more fully developed. The same mode of development may be

traced in *Chalina oculata*, but not to such an extent as in *Isodictya palmata*. In the sessile massive species of Halichondroid sponges the same mode of development seems to obtain, as I have frequently traced the different stages of growth in sections at right angles to the surface of the sponge.

ON THE CLASSIFICATION OF THE SPONGIADÆ.

While the arrangement of other subjects of natural science has occupied the attention of some of the most laborious aud talented naturalists of every age, the Spongiadæ appear to have scarcely attracted sufficient attention to have excited any writer on natural history to a serious attempt at a systematic classification. This neglect has not arisen from any incapacity for a definite arrangement on the part of the Spongiadæ, as the organic differential characters of the numerous groups into which, by careful examination, they may be readily divided are as varied and as widely removed from each other as are the strikingly distinct and well defined divisions of the Corallidæ, and the number of species I believe to be very much greater than those of the latter class. Of British species alone I am already acquainted with more than 150, and new ones are continually being discovered by the aid of the dredge. It becomes therefore a matter of necessity that we should classify their permanent varieties of structure, and found on them a series of orders, suborders and genera, and through these subdivisions become enabled to recognise more readily the very numerous species of these animals which abound in all parts of the world.

De Blainville proposed to include the whole of the Spongiadæ under the designation of Amorphozoa; but this term is objectionable, as all sponges cannot be considered as shapeless, on the contrary many genera and species exhibit much constancy in their form. Neither can the term be justly applied to their internal structure, as we find

in *Grantia*, *Geodia*, *Tethea*, and other genera, regular and systematical structures which are very far removed from shapelessness. I have therefore thought it advisable to adopt Dr. Grant's designation of Porifera, a term which embraces the whole of the Spongiadæ, and which is truly descriptive of the most essential general action of the animal's power and mode of imbibing nutriment, which in every species with which I am acquainted is, by a series of minute pores, distributed over the external membrane of the sponge.

Besides this universally existent character there are others which are strikingly characteristic of the class, although not so universally prevalent as the porous one. Thus the skeletons of the Spongiadæ are always internal, but in the material and mode of construction they vary to a very considerable extent. Sponges may therefore be defined as fixed, aquatic, polymorphous animals; inhaling and imbibing the surrounding element through numerous contractile pores situated on the external surface; conveying it through internal canals or cavities, and ejecting it through appropriate orifices; having an internal flexible or inflexible skeleton, composed of either carbonate of lime, silex, or keratode; with or without either of these earthy materials. Calcareous skeletons always spicular. Siliceous skeletons either spicular or composed of solid, laminated, and continuous siliceous fibre.

Propagation by ova, gemmulation, or spontaneous division of its component parts.

Dr. Grant, in his learned and elaborate 'Tabular View of the primary divisions of the Animal Kingdom,' published in 1861, has divided the Porifera into three orders, based on principles which I have adopted. The first order is *Keratosa*, in which the skeletons are essentially keratose and fibrous; the second, *Leuconida*, is composed of the calcareous sponges; and the third, *Chalinida*, consisting of the siliceous sponges. I have not adopted the full and precise definition of each of these Orders as given by the learned Professor, as, if the whole of the distinctive characters in the first and third of them were insisted on in

the determination of the orders to which many exotic species belong, it would lead in numerous cases to inextricable confusion. The term *Leuconida* is also objectionable, as all calcareous sponges are not white, and colour is at best but a very uncertain character even in the determination of a species; I have therefore adopted the principles of the arrangement of Professor Grant, with the following modifications of position and descriptions of the characteristics of each order.

1. Calcarea. Sponges the skeletons of which have as an earthy base carbonate of lime.

2. Silicea. Sponges in which the earthy base consists of siliceous matter.

3. Keratosa. Sponges in which the essential base of the skeleton consists of keratose fibrous matter.

While thus assuming the principles of arrangement enunciated by the learned Professor, I have been induced to vary the mode of the disposition of his Orders from the following considerations.

In the highest vertebrated animal types we invariably find the skeleton principally composed of phosphate of lime with a small portion of carbonate of lime and other substances, the whole consolidated by cartilage. As we descend the scale of the Vertebrata we find the salts of lime decrease in proportional quantity until they occur in minute detached patches only, and cartilage becomes the essential base of the skeleton.

In the great tribe of Mollusca we find carbonate of lime prevailing in their shells to the exclusion of phosphate of lime, and in the compound Tunicata we have a structure analogous to that of the cartilaginous tribe of Fishes. In the massive subcartilaginous body of this tribe there is no continuous or connected earthy deposits. This material of the skeleton exists only in the form of detached masses of radiating spicula. As we descend in the animal scale we find carbonate of lime entirely absent, and silex replacing it in the elaborate and beautifully constructed loricæ of the marine and freshwater infusoria.

If we are to reason from these gradations of structure

and apply our reasoning to the Spongiadæ, we should then give precedence to the calcareous sponges as representing in the class the highest order of secretive power; and if we add to these considerations the regularity of structure and function and the full development of ciliary action that exists in *Grantia ciliata* and *compressa* and the allied species, I think it scarcely allows of a doubt that this order should take precedence of the others in an arrangement of the Spongiadæ.

The siliceous sponges naturally follow in succession, and the Keratosæ, from their imperfect secretive powers and their low order of organization in other respects, would indicate their position to be the last in the series.

ON THE GENERIC CHARACTERS OF THE SPONGIADÆ.

The foundation of the genera of the Spongiadæ has hitherto been based principally upon form and other external characters of an equally unstable description, and in many instances genera have been named without the slightest attempt to characterise them. As a generic character form is inadmissible, inasmuch as each variety of it is found to prevail indiscriminately in genera differing structurally to the greatest possible extent.

I will not enter on the history of the genera that have been proposed by previous writers on the Spongiadæ, as the greater portion of those which have been published will hereafter be found to have been adopted, with certain revisions of their characters, in the series of genera I propose to establish, but I shall beg to refer such of my readers as may be desirous of further information on that subject to page 70 of Dr. Johnston's admirable introduction to his 'History of British Sponges and Lithophytes.'

Having thus rejected form and other external characters as the foundation of generic descriptions, we naturally resort to the anatomical peculiarities of the animal for these purposes; and here fortunately we find a variety in structure and form, and a constant adherence to their respective types that admirably adapt them to our purpose.

If any portion of the animal remains, whereby we may recognise it as one of the Spongiadæ, it is always the skeleton, and it is therefore advantageous to adopt this most persistent portion of the animal as the foundation of our generic descriptions. But this is not the sole reason for such a conclusion, as it is not only the most enduring portion of the animal, but it is also the most undeviatingly regular in the form and arrangement of its component structures. However great may be the variations that exist in size and form between different species of the same genus, or between individuals of the same species, the characteristic tissues of their skeletons are always found to harmonise in their structural peculiarities. It appears, therefore, advisable in these animals, as well as in the higher classes, to select the skeleton as the primary source of generic distinctions. Other portions of the permanent organs may be occasionally resorted to when necessary as auxiliary characters, such as the incurrent and excurrent canals, the intermarginal cavities, the cloaca, and the various modes of reproduction. Each of these characters are of use in generic descriptions to a certain extent, but none of them are absolutely necessary to the determination of a genus, and occasionally we find one or more of these modes of organization entirely absent; we may therefore consider them not as primary, but rather as secondary or auxiliary generic characters.

I therefore propose to consider the varieties in the construction of the skeleton as the foundation or primary source of divisions into genera, and to dedicate that portion of the animal especially to that purpose; the auxiliary or secondary characters being resorted to only when required to aid and assist the primary ones; and it is only to a very limited extent that they are in reality available. Thus the cloaca in the Order Calcarea becomes a very important means of generic distinction, and in some cases in the Order Keratosa it is also a prominent character, while in Silicea it is generally absent. In some species of this order, as in *Alcyoncellum*, *Polymastia*, and *Halyphysema*, it assumes a normal character, while in several species of

Halichondria, and in *H. panicea*, it assumes very striking proportions in excessively developed specimens, whilst in others it is either an occasional, uncertain, and progressive organ, or is altogether absent.

The mode of propagation is also an uncertain character. Thus in *Tethea cranium* we find it to be by internal gemmulation; in *T. lyncurium* by external gemmules; and in other species of the genus no gemmules of any description have hitherto been detected. In *Geodia*, *Pachymatisma*, and *Spongilla* the general structure and mode of disposition of the ovaria render them valuable auxiliary generic characters, but in other cases they are of little or no value.

The intermarginal cavities are available as generic characters in *Geodia* and the nearly allied species, and in the same sponge the relative position of the connecting spicula form good distinctive characters in the genera *Geodia*, *Ecionemia*, and also some of the siliceo-fibrous sponges. In *Alcyoncellum*, *Polymastia*, and *Geodia* the position and appendages of the oscula are also available, but generally speaking those organs are so mutable as to render them of little value as generic characters.

The following tabular view of the arrangement I propose to adopt, will perhaps render the details regarding the distinctive characters and natural affinities of the genera more readily comprehensible.

Tabular View of Systematic Arrangement.

Class.	*Order.*	*Suborder.*	*Genera.*
PORIFERA.	I. CALCAREA		Grantia, *Fleming.*
			Leucosolenia, *Bowerbank.*
			Leuconia, *Grant.*
			Leucogypsia, *Bowerbank.*
	II. SILICEA...........	1. Spiculo-radiate skeletons	Geodia, *Lamarck.*
			Pachymatisma, *Bowerbank.*
			Eciomemia, *Bowerbank.*
			Alcyoncellum, *Quoy et Gaimard.*
			Polymastia, *Bowerbank.*
			Halyphysema, *Bowerbank.*
			Ciocalypta, *Bowerbank.*
			Tethea, *Lamarck.*
			Halicnemia, *Bowerbank.*
			Dictyocylindrus, *Bowerbank.*
			Phakellia, *Bowerbank.*
			Microciona, *Bowerbank.*
			Hymeraphia, *Bowerbank.*
			Hymedesmia, *Bowerbank.*
		2. Spiculo-membranous skeletons	Hymeniacidon, *Bowerbank.*
		3. Spiculo-reticulate skeletons	Halichondria, *Fleming.*
			Hyalonema, *Gray.*
			Isodictya, *Bowerbank.*
			Spongilla, *Linnæus.*
		4. Spiculo-fibrous skeletons	Desmacidon, *Bowerbank.*
			Raphyrus, *Bowerbank.*
		5. Compound reticulate skeletons	Diplodemia, *Bowerbank.*
		6. Solid siliceo-fibrous skeletons	Dactylocalyx, *Stutchbury.*
		7. Canaliculated siliceo-fibrous skeletons....................	Farrea, *Bowerbank.*
	III. KERATOSA	1. Solid non-spiculate kerato-fibrous skeletons	Spongia, *Linnæus.*
			Spongionella, *Bowerbank.*
		2. Solid semispiculate kerato-fibrous skeletons	Halispongia, *Blainville.*
		3. Solid entirely spiculate kerato-fibrous skeletons	Chalina, *Grant.*
		4. Simple fistulo-fibrous skeletons.	Verongia, *Bowerbank.*
		5. Compound fistulo-fibrous skeletons........................	Auliskia, *Bowerbank.*
		6. Regular semi-areno-fibrous skeletons.....................	Stematumenia, &c., *Bowerbank.*
		7. Irregular and entirely areno-fibrous skeletons	Dysidea, *Johnston.*

Order I. CALCAREA.

The number of species of calcareous sponges that are known are comparatively so few, and the four genera into which I have divided them are naturally so well characterised as to render the establishment of suborders unnecessary. Hereafter, when we are acquainted with a greater number of species and other varieties of organization become known, the genera now established may become the types of suborders, for which office their distinctly different modes of construction render them eminently efficient.

Although the calcareous structure of the species of this order appear to entitle it to precedence in the arrangement of the Spongiadæ, it does not maintain in the structure of its skeleton throughout the whole of the genera the same high type of formation that is exhibited in *Grantia compressa,* Johnston, and the allied species, and we observe a progressive decline in regularity of structure in its genera very analogous to what we find existing among the Halichondroid tribe of sponges; but in this respect they only follow the same laws of gradual degradation that obtain in every other class of created beings, and this gradual decline in regularity of structure should not therefore militate against the claim of even the lowest in organization of the tribe from taking precedence of the siliceous sponges.

Dr. Grant was the first naturalist who decided that the spicula of a certain group of small sponges were composed of carbonate of lime, and he separated them accordingly from those the spicula of which were siliceous, and assigned to them the generic name of *Leucalia* ('Edinburgh Encyclopædia,' vol. xviii, p. 844); and subsequently, in his 'Outlines of Comparative Anatomy,' he changed that name to *Leuconia.* In 1828 Dr. Fleming gave to the group the name of *Grantia,* in compliment to the learned naturalist who had first pointed out their peculiar structure.

A careful examination of the British species of this Order will very soon satisfy a naturalist that there are at least four distinct forms in the organization of the skeleton, and that each is fully entitled to generic distinction. Thus in *Grantia ciliata* and *compressa,* Johnston, we find the sponge to be constructed of a series of cells, each having separate parietes, and extending from the dermal surface to near the inner surface of the sponge, where they discharge the fæcal streams into a common cloacal cavity. In *Grantia botryoides,* Johnston, the system of cells is entirely wanting; the sponge is composed of a single thin stratum of membranous structure and spicula, surrounding a large cylindrical cloacal cavity, from the terminations of which the fæcal streams are discharged. In *Grantia nivea,* Johnston, we find the sponge massive and irregular in form, containing numerous capacious cloacal cavities, each terminated by a single large mouth, the interstitial structures between the sides of these great cavities and the dermal surfaces of the sponge consisting of irregularly disposed membranes and spicula, permeated by contorted interstitial cavities, terminating in simple orifices or oscula in the sides of the great fæcal cavity, into which they discharge their excurrent streams; and in *Leucogypsia Gossei,* Bowerbank, the sponge is massive, without cloaca, formed of irregularly disposed membranous tissues and spicula, and with oscula at the external surface, thus simulating to a great extent the mode of structure of the Halichondroid tribes of sponges.

The sponges of this Order appear to possess a high degree of vital power, and I have rarely failed in finding the excurrent orifices in vigorous action in either *Grantia compressa, ciliata,* or *botryoides* when recently taken from the sea. In *G. compressa,* especially, I have often observed the inhalant and exhalant actions remarkably vigorous; and if a drop of water containing finely comminuted indigo be mixed with the water in which they are immersed, they will become deeply tinctured with it in a very few seconds. This vigorous action is accounted for by the highly developed ciliary system, which may be readily seen in action

if the sponge be carefully split open and immersed in fresh cold sea-water, and examined with a power of about five or six hundred linear by transmitted light. The cilia will be seen in rapid action just within the oscula which terminate each of the large angular interstitial cells of the sponge. This action, and the mode of the disposition of the cilia within the cells, I have described at length in the 'Transactions of the Microscopical Society of London,' vol. iii, p. 137, pl. xix. In accordance with these variations in structure I purpose dividing the British species into four genera.

Class—**PORIFERA**, *Grant.*

Order I.—CALCAREA.

Genera. Grantia.
Leucosolenia.
Leuconia.
Leucogypsia.

Grantia, *Fleming.*

Sponge. Furnished with a central cloaca, parietes constructed of interstitial cells, more or less regular and angular in form, disposed at right angles to the external surface, and extending in length from the outer to very near the inner surface of the sponge, where each terminates in a single osculum.

Type, *Grantia compressa,* Johnston.

The cloaca varies in its form and proportion. In some species it has invariably one large terminal mouth, while in others it is furnished with several mouths from which the excurrent fæcal streams are discharged.

The interstitial structures of the sponges of this genus

assumes a greater amount of regularity than is found to exist in any other genera of these animals. The whole of the parietes of the sponge are formed of somewhat angular cells, the sides of which belong to the individual cell, and are not common to each other. The lengths of the cells in proportion to their diameters vary in different species, and also in the same species in proportion to the age and thickness of the parietes of the sponge. The cell-walls are formed of comparatively stout transparent membrane, strengthened and supported by numerous triradiate spicula, and the whole length of the cell from the inner edge of the osculum to near the outer surface of the sponge is closely studded with tesselated nucleated cells, each of which is furnished with a long attenuated cilium. Each interstitial cell terminates in a single osculum, slightly within the plane of the inner surface of the sponge. I do not remember to have ever seen these oscula entirely closed. When the inhalant action of the sponge is in vigorous operation, the excurrent streams may be seen issuing from them with considerable force, and the cilia appear in action immediately within them.

Hitherto the mouths of the great cloacal cavity of the sponges of this tribe have been described as Oscula; but if we carefully examine the structure of these and similarly formed sponges, we shall find in all cases that those organs exist only on the inner surface of the great cloacal cavities.

The construction of the interstitial cells is best demonstrated in a longitudinal section of a dried specimen of *Grantia ciliata,* mounted in Canada balsam, and in a specimen so prepared spaces are seen between the cells which are often nearly half the size of the cells. These spaces are most probably produced by the contraction of the tissues induced by the mode of the preparation of the object, and do not exist in the living sponge, but they serve admirably to demonstrate the fact that each interstitial cell has its own special parietes, and that the divisions between the cells are not common to each other. Figs. 312, 313, Plate XXI, and figs. 345, 346, *a,* Plate XXVI.

LEUCOSOLENIA, *Bowerbank.*

GRANTIA, *Fleming* and *Johnston.*

Sponge. Fistular. Formed of a single layer of triradiate and other spicula, surrounding a large central cloaca, which extends into all parts of the sponge.

Type, *Grantia botryoides*, Fleming.

The structure of *Grantia botryoides,* Fleming, differs essentially from that of *Grantia compressa* of that author, inasmuch as there is a total absence of the interstitial cells which are so characteristic of the latter sponge; and its structure is equally discrepant when compared with that of *Grantia nivea* of Fleming; for although it possesses cloacæ in common with that species, it has no approximation whatever to the massive Halichondroid form of the substance of that sponge. On the contrary, its parietes consist of a single thin layer of spicula and membranous tissues surrounding a large central sinuous cloaca. Figs. 347, 348, Plate XXVI.

LEUCONIA, *Grant.*

GRANTIA, *Fleming* and *Johnston.*

Sponge. Furnished with cloacæ, one or more. Parietes of sponge formed of a mass of irregularly disposed interstitial membranes, and triradiate and other spicula; permeated by sinuous excurrent canals, the oscula of which are irregularly disposed over the surfaces of the cloacæ.

Type, *Grantia nivea*, Fleming.

Grantia nivea of Dr. Fleming is very different in its structure from either *G. compressa* or *ciliata,* or of *G. botryoides* of that author. It has not the regular inter-

stitial structure of either of the first two, nor the simple fistulose form of the latter one; but with the exception of the form of the spicula, it closely simulates the structural character of the siliceous genus *Halichondria*, while it is allied with the before-named calcareous sponges by the possession of cloacæ. In consequence of these marked differences in the structure of the skeleton, I have separated it from *Grantia* as defined by Dr. Fleming, and constituted it a genus, adopting the term *Leuconia*, which was proposed by Dr. Grant as a general designation of the whole tribe of calcareous sponges. Figs. 351, 352, Plate XXVII.

LEUCOGYPSIA, *Bowerbank*.

Sponge. Massive, without cloacæ; formed of irregularly disposed membranous tissues and spicula. Oscula at the external surface.

Type, *Leucogypsia Gossei*, Bowerbank.

The sponges of this genus are still further removed in structural character from the higher organized genera of calcareous sponges *Grantia* and *Leucosolenia* than the genus *Leuconia* is. In the arrangement of the interstitial membranes, and the mode of dispersion on them of the skeleton spicula, there is a manifest similitude to the structural peculiarities of the genus *Hymeniacidon* among the Siliceæ, and we find a corresponding simplicity in the characters of the spicula in *Leucogypsia*, the type of this genus. There are no regularly determined cloacæ projected from the surface as in *Leuconia*, and the excurrent canals of the sponge merge in each other, until they unite in one large canal immediately beneath the osculum, in the manner generally prevailing in the great mass of Halichondroid sponges. These large canals have defensive spicula similar in structure to those of the other genera of calcareous sponges. The only known British species of this genus is *L. Gossei*, Bowerbank; but I am acquainted with an exotic

species, *L. algoaensis*, Bowerbank, MS., which is not uncommon on specimens of Zoophytes and Fuci from Algoa Bay and its neighbourhood. Figs. 349, 350, Pl. XXVI.

Order II.—SILICEA.

The genus *Halichondria*, as established by Fleming and adopted by Dr. Johnston, when applied to the arrangement of exotic as well as British species, embraces so wide a range as to afford but little assistance in the determination of species. Under this designation every known sponge would be arranged having silex as the earthy basis of its skeleton, however varied their anatomical structure might be, excepting the few species contained in the genera *Geodia*, *Tethea*, and *Spongilla*.

Dr. Johnston, in his 'History of British Sponges,' has divided the British species into three sections, dependent on their form, a character so mutable among the Spongiadæ, as to render it of little value under any circumstances, when unaccompanied by structural peculiarities. I have therefore thought it advisable to distribute the genera included in the order Silicea among seven suborders, founded on the most striking peculiarities of the structure of the skeleton.

The first of these will consist of sponges having spiculo-radiate skeletons. Skeletons not reticulated, but composed of spicula radiating in fasciculi or separately from the base or axis of the sponge. This order will contain as many as fourteen distinct genera, the whole of which have skeletons the spicula of which are arranged in radial order. The mode of the radiation in these fourteen genera is not precisely the same, but they form three closely according groups, of which the leading genus of each of the first two may be considered as the type.

1. *Geodia*, Lamarck.
2. *Pachymatisma*, Bowerbank.
3. *Ecionemia*, Bowerbank.
4. *Alcyoncellum*, Quoy et Gaimard.
5. *Polymastia*, Bowerbank.
6. *Halyphysema*, Bowerb.
7. *Ciocalypta*, Bowerbank.

The second group contains :

1. *Tethea*, Lamarck.
2. *Halicnemia*, Bowerb.
3. *Dictyocylindrus*, Bowerb.
4. *Phakellia*, Bowerbank.

In the whole of the first two groups, excepting *Halyphysema*, the skeleton radiations are fasciculated to a greater or less amount in the different genera.

The third group will comprise :

1. *Microciona*, Bowerbank.
2. *Hymeraphia*, Bowerbank.
3. *Hymedesmia*, Bowerbank.

The most striking general character in these three genera is the extremely thin coating form of the sponge, and the radiation of the skeleton spicula, either singly or in an irregularly fasciculated form, from a common basal membrane, the thickness of the sponge in some of the species being less than the length of one of the radiating skeleton spicula.

Suborder I. Spiculo-radiate skeletons. Not reticulate. Composed of spicula radiating in fasciculi or separately from the base or axis of the sponge.

GEODIA, *Lamarck.*

Skeleton. Spicula fasciculated, radiating from the base or central axis of the sponge to the surface. Dermis crustular, furnished abundantly with closely packed ovaria. Ovaria siliceous, composed of cuneiform spicula, firmly cemented together by silex, in lines radiating from the centre of the ovary. Pores furnished with œsophageal tubes, terminating in the distal extremity of the intermarginal cavities. Inter-

marginal cavities separate, symmetrical, subcylindrical; each furnished with a membranous valve at its proximal extremity.

Type, *Geodia gibberosa,* Lamarck.

The genus, as described by Lamarck,* is so loosely characterised that I have thought it better to reconstruct it entirely than to endeavour to amend it. I have therefore given a new series of characters, founded solely on its structural and organic peculiarities. I am acquainted with seven species, all of which perfectly agree in the essential generic characters as thus constructed.

The type specimen of Lamarck's *Geodia gibberosa* in the Museum of the Jardin des Plantes of Paris, the organization of which, through the kindness of Professors Milne-Edwards and Valenciennes, I have had an opportunity of thoroughly examining, is unfortunately in so deteriorated a condition in many respects, and especially in regard to the dermal membrane and pores, that I have been induced to select *G. Barretti* from which, to a great extent, to describe the interesting and highly organized structures of this genus; and I have the advantage also in this species of having a portion of a specimen which has never been deteriorated by drying, having been pickled in strong salt and water immediately on being taken from the sea, by my friend Mr. McAndrew, and in this state it closely resembles a mass of somewhat indurated animal liver.

The skeleton is composed of continuous fasciculi of stout long spicula, which in massive specimens radiate from the base to the outer surface of the sponge; or if the species be of an elongated form, from the central axis to the circumference, where in either case they terminate at the inner surface of the crustular dermis, intermixing with, and being firmly cemented to, the shafts of the expando-ternate connecting spicula, which are attached to and firmly support

* "Polyparium liberum, carnosum, tuberiforme intùs cavum et vacuum, in sicco durum; externâ superficie undique porosâ. Foramina poris majora in areâ unicâ orbiculare et laterali observata." (Lamarck, 'Ann. s. Vert.,' 2de edit., ii, 593.

the inner surface of the crustular dermis. Fig. 354, Plate XXVIII.

The organization of this external crust is exceedingly interesting. The outer surface is composed of a uniform thin pellucid dermal membrane, perforated with innumerable minute pores, variable in their diameter, and apparently possessing the power of opening or closing at the will of the animal. Immediately beneath the dermal membrane there is a stratum of sarcode of variable thickness in different species, and this stratum is permeated by numerous short canals, connecting the external pores with the intermarginal cavities which occupy, at nearly equidistant points, the thick stratum of ovaria forming the inner layer of the crustular dermis. In dried specimens, the positions of the intermarginal cavities are usually indicated on the surface of the sponge by a series of dimples or pits, frequently assuming, by the contraction of the dermal membrane, more or less of a stellated appearance. The proximal extremities of these organs is at the inner surface of the stratum of ovaria, and the distal extremities at the outer surface of the same stratum; and this termination has usually a greater diameter than the proximal end, which is furnished with a stout contractile diaphragm or pyloric valve.

The expando-ternate spicula, which are situated at the distal extremities of the radial fasciculi of the skeleton, diverge slightly from each other from their basal extremities, so that their triradiate heads, when firmly cemented to the inner surface of the ovarian stratum, form a strong and regular siliceous network, the points of the radii of each being cemented by keratode to those of its next neighbour; and within the area of each of these meshes of the network there is the proximal end of an intermarginal cavity, the diaphragm of which frequently occupies the greater portion of the area, having a much greater diameter than that of the proximal orifice of the cavity, so that when fully opened its orifice is quite equal to that of the intermarginal cavity. The ovaries vary considerably in size in different species. In the adult and prolific condition they have the form of a

strong, thick-shelled, more or less globose ovarium, having a funnel-shaped orifice at the apex, which communicates with the central cavity, which, in the prolific state, is filled with closely-packed minute vesicular bodies, very similar in appearance to those contained in the ovaria of the Spongillidæ, but apparently more minute. In this condition of the ovary its parietes are formed of acutely cuneiform spicula, firmly cemented together by siliceous matter, the united apices forming the inner surface of the ovarium, while the united truncate bases form the external surface. In the early and immature state of the ovaria these truncated bases are not produced, and the young ovary has its outer surface bristling with pointed spicula, which are most acute in the youngest specimens, and becoming gradually more obtuse as they approach maturity. After the prolific contents of the adult ovary has been liberated, the internal cavity is gradually filled up by the extension inwards of the apices of the cuneiform spicula until it becomes eventually a solid body; and a similar secretion of siliceous matter is also frequently continued at the outer surface until it often assumes an irregular tuberous and quite abnormal appearance.

The ovarian stratum of the crustular dermis is principally composed of exhausted solid ovaria, but occasionally near the outer surface of the stratum a few prolific ones may be observed; but the greater number of these bodies and of those in an early stage of development, are situated amid the deeply-seated portions of the sponge, scattered irregularly over the sarcodous membranes and deeply immersed in the sarcode. In the young state they each appear to be surrounded by a firm stratum of sarcode, which, from its perfectly smooth and circular form, is apparently contained within a proper membrane, but in the fully developed and in the exhausted ovaria this sarcodous envelope is not observable. This description of the organization of the genus will apply equally well to any one of the seven species with which I am acquainted, and also to the nearly allied genus *Pachymatisma*, excepting the mode of the arrangement of the skeleton in the latter.

Both the type specimens of *Geodia* in the Museum at the Jardin des Plantes appear to have had large central cavities, but I have not found similar excavations in other species of the genus excepting in one instance, a *Geodia* from Port Elliot, Australia; the internal surface in each of the three cases presents precisely the same appearance, a simple irregularly matted surface of spicula and membranes without any thickening of the tissues, and differing in no respect from the surfaces of any of the smaller internal cavities of the sponge. I am therefore inclined to consider such excavations as abnormal occurrences, which are not entitled to be considered as of either generic or specific value. Fig. 354, Plate XXVIII, represents a section at right angles to the surface of *Geodia Baretti*, Bowerbank, MS., *a, a*, longitudinal sections of two of the intermarginal cavities; *b, b*, the basal diaphragms of the intermarginal cavities; *c, c*, the imbedded ovaria forming the dermal crust of the sponge; *d, d*, the large patento-ternate spicula the heads of which form the areas for the valvular bases of the intermarginal cavities; *e, e*, recurvo-ternate spicula within the summits of the great intercellular spaces of the sponge; *f, f*, portions of the interstitial membranes of the sponge crowded with minute stellate spicula; *g, g*, portions of the secondary system of external defensive spicula × 50 linear. See also Figs. 301, 302, Plate XIX. Fig. 301 represents a small portion of the inner surface of the dermal crust *Geodia Barretti* with two of the valvular membranes of the proximal ends of the intermarginal cavities; *a*, valve closed; *b*, valve partly open; *c*, portions of the patento-ternatespicula imbedded in the tissues and forming the areas for the valvular terminations of the intermarginal cavities × 50 linear.

PACHYMATISMA, *Bowerbank*.

Skeleton composed near the external surface occasionally of short fasciculi of siliceous spicula, disposed in lines at about right angles to the surface of the sponge. Central portion of the sponge unsymmetrical. Der-

mis crustular, furnished abundantly with closely packed ovaria. Ovaria siliceous, formed of cuneiform spicula, firmly cemented together in lines radiating from the centre of the ovary. · Pores furnished with œsophageal tubes, terminating in the distal extremity of each intermarginal cavity. Intermarginal cavities symmetrical, subcylindrical, with a pyloric valve at the proximal end of each.

Type, *Pachymatisma Johnstonia*, Bowerbank.

Since the first publication of my description of the sponge on which this genus is founded in the "Synopsis Spongiarum" of Dr. Johnston's 'History of British Sponges,' p. 243, I have found it necessary to base the generic characters of the Spongiadæ on the structural peculiarities of the skeleton and reproductive organs. I have therefore reconstructed the character of the genus in accordance with this rule.

This genus is closely allied to *Geodia* in its organic structure, but the difference in the arrangement of the skeleton readily distinguishes them. The general aspect of the species of each genus is also strikingly distinct. I am acquainted with seven species of *Geodia* and three of *Pachymatisma*, and in every case the species may be readily referred to its proper genus even by its general aspect. All the species of either genus have a crustular dermis, and the structures of the ovaria are also alike in each. I have described the anatomical peculiarities of the latter organs so fully in the description of the generic characters of *Geodia* as to render it unnecessary to treat of them under the present circumstances. Fig. 353, Plate XXVII, a view of a section at right angles to the surface from *Pachymatisma Johnstonia*, exhibiting the irregularity of the interstitial structures immediately beneath the dermal crust × 50 linear.

ECIONEMIA, *Bowerbank.*

Sponge. Having a strong axial column or centre of closely packed siliceous spicula disposed in lines parallel to the long axis of the sponge, from which axial column or centre a peripheral system of spicula radiates at about right angles. Distal ends of the radii furnished more or less with ternate connecting spicula, the radii of which are disposed immediately beneath the dermal membrane.

Type, *Ecionemia acervus,* Bowerbank, MS.

This genus differs from *Dictyocylindrus* in having the axial column composed of a dense mass of parallel spicula instead of a column formed of an open network of spicula; and the peripheral system is also different, inasmuch as it is essentially a portion of the interstitial system of the sponge, and not more especially a defensive system as it appears in *Dictyocylindrus;* in no species of which genus has there ever yet been found ternate spicula at the surface, while in *Ecionemia acervus,* the type species of the genus, they are abundant.

The structure of the peripheral system exhibits a close alliance with the genera *Pachymatisma* and *Tethea. Ecionemia* differs from *Geodia* and *Pachymatisma* in the total absence of the siliceous ovaries, and of the crustular dermal coat formed principally of those bodies in the last-named genera. There are also no cylindrical valvular intermarginal cavities, and the ternate apices of the connecting spicula appear always to be applied to the inner surface of the dermal membrane. This arrangement of the tissues therefore forms a natural transition from *Pachymatisma* to *Tethea,* in some species of which genus the ternate spicula are found without the dermal membrane in the porrecto-ternate form, and are adapted to defensive purposes, while in others they occur immediately beneath it as patento-ternate connecting spicula. I have therefore assigned this genus a position between *Pachymatisma* and *Dictyocylin-*

drus. Fig. 355, Plate XXVIII, represents a view of a section at right angles to the surface exhibiting the radial fasciculi of the peripheral system with the ternate apices of the spicula immediately beneath the dermal membrane × 50 linear.

We have no British species of this genus; the type species, *Ecionemia acervus*, Bowerbank, MS., is in the Museum of the Royal College of Surgeons of London.

ALCYONCELLUM, *Quoy* et *Gaimard* (*Euplectella*, Owen).

Professor Owen, in his paper on *Euplectella aspergillum*, Owen, communicated to the Zoological Society January 26, 1841, and published in the 'Transactions of the Zoological Society of London,' vol. iii, part 2, p. 203, pl. xiii, appears to have fallen into a singular number of errors in the course of his description of this beautiful sponge. He has, in the first place, designated it as belonging to the Alcyonoid family, apparently only because it is cylindrical in form and reticulate in structure, but without the slightest reference to the polyps that must necessarily characterise an Alcyonium; and he proceeds in his description to describe the base of the sponge as its apex and the apex as its base. The author then notices the first specimen of this genus that was made known to us by MM. Quoy and Gaimard, in the 'Zoologie de l'Astrolabe,' 8vo, 1833, p. 302, planches fol. Zoophytes, fig. 3, pl. xxvi, but unfortunately mistakes the generic name *Alcyoncellum*, applied to the sponge by the French authors, for *Alcyonellum;* and having mistaken its name, its base, and its apex, he proceeds to reason on its generic characters thus:—"If the basal aperture of the cone were open, the resemblance to some of the known reticulate Alcyonoid sponges would be very close, especially to that called *Alcyonellum gelatinosum* by M. de Blainville, 'Manuel d'Actinologie,' 8vo, 1834, p. 529 (*Alcyonellum speciosum*, Quoy et Gaimard): its closure by the reticulate convex frilled cap, in the present instance, establishes the generic distinction; and in

the exquisite beauty and regularity of the texture of the walls of the cone, the species surpasses any of the allied productions that I have yet seen or found described. I propose, therefore, to name it *Euplectella aspergillum*." In note 5 appended to this paper, Professor Owen also says, "If the recognition of the generic or specific identity of the specimen here figured be impracticable by reason of its mutilated condition, the generic name applied to it cannot be adopted while the Lamarckian genus of fresh water polyps, *Alcyonella*, is retained in Zoology." Now as it is manifest that the reasoning of Professor Owen in favour of his proposed genus *Euplectella* is based, not upon one only, but upon a series of errors, and as he has not attempted to characterise his own genus, while that of *Alcyoncellum*, Quoy et Gaimard, is regularly described in the 'Histoire Naturelle des Animaux sans Vertèbres' by Lamarck, 2nd Edit., vol. ii, p. 589, printed in 1836, it is evident that the generic name of the French authors must take precedence of that proposed by Professor Owen.

The following is the generic description of MM. Quoy et Gaimard:

"*Genre* ALCYONCELLE (*Alcyoncellum*).

Spongiare, lamelleux, dont la charpente est formée de filets très déliés, accolés les uns aux autres et entre croisés de manière à former des mailles nombreuses, arrondies, assez régulières, et semblables à celles d'une dentelle."

In this generic description the material of which the sponge is formed is not in the slightest degree indicated, and the description of its structural peculiarities is so general that it will apply equally well to almost every known fistulose sponge. I have therefore thought it necessary to arrange the sponges of this genus with their congeners in material and mode of construction, and to recon-

struct the generic characters so as to endeavour to limit the genus within definite bounds. I propose therefore to substitute the following characters for those of the French authors.

ALCYONCELLUM, *Quoy* et *Gaimard.*

EUPLECTELLA, *Owen.*

Sponge fistulate ; fistula single, elongate, without a massive base. Skeleton : primary fasciculi radiating from the base in parallel straight or slightly spiral lines ; secondary fasciculi at right angles to the primary ones. Oscula congregated, with or without a marginal boundary to their area.

Type, *Alcyoncellum corbicula,* Quoy et Gaimard.

The congregation of the oscula in *Alcyoncellum corbicula* and *aspergillum* is not a character peculiar to those sponges. A similar mode of arrangement exists in several species of *Geodia.* In *G. gibberosa,* in the Museum of the Jardin des Plantes at Paris, they are congregated in an area with a well-defined boundary, and in specimens of *G. Barretti* in my possession they are situated in deep depressions or cavities on the surface of the sponges ; and these cavities or areas are not uniform in either shape or size ; so we may infer that the presence in some species of *Alcyoncellum* of a well-defined marginal boundary to the oscular area, and its absence in other species, amounts to a specific difference rather than to a generic distinction ; but in either case the oscular are congregated at the distal extremity of the sponge, and the areas of its parietes are the inhalant portions of the animal. The inhalation and exhalation of water is precisely on the same principle as that which obtains in *Grantia ciliata ;* the whole of the parietes are appropriated to inhalation, the incurrent streams are passed through the interstitial cavities and discharged into a common cloaca, and the effete stream ejected at the distal

extremity of the sponge; the essential difference being that in *Grantia* the distal end of the cloaca is open, and in *Alcyoncellum* it is partially closed by a cribriform veil, the orifices of which appear to be the true oscula of the sponge. And this opinion is justified by the structure of the numerous cloacæ in the closely-allied genus *Polymastia*, where we find the orifices through which the incurrent streams are poured into the cloaca permanently open.

All the known species of this genus appear to consist of a single fistulose body, and some of them are apparently of a parasitical habit. *Alcyoncellum aspergillum* (*Euplectella aspergillum*, Owen) especially is furnished with numerous recurvo-quaternate spicula at its base, by which it attaches itself to sponges or other bodies. These prehensile organs do not appear in all the species of the genus, and in one perfect and beautiful specimen in the Museum of the Jardin des Plantes at Paris the base is closed, and is entirely destitute of prehensile spicula. The attachment of the sponge is partly, on one side, in the form of a thick incrustation, and partly, close to the base, by a similar patch of thickened tissue. There is also another striking difference in its structure, and that is the absence of the raised margin to the oscular area at the apex of the sponge. In other structural characters it agrees exceedingly closely with *A. aspergillum*.

Fig. 356, Plate XXIX, is a view of a small portion of the surface of Mr. Cuming's specimen of *Alcyoncellum aspergillum*, exhibiting the mode of disposition of the inhalant areas; *a*, the primary fasciculi of the skeleton; *b*, the secondary fasciculi, plus about 5 linear. Fig. 357 represents the congregated oscula within their marginated area at the distal termination of the sponge. Natural size.

POLYMASTIA, *Bowerbank*.

Skeleton. Basal mass. Central portion consisting of a plexus of contorted anastomosing fasciculi, resolving themselves near the surface into short straight bundles

disposed at nearly right angles to the surface. Oscula congregated, elevated on numerous long fistulæ. Fistulæ composed of numerous parallel fasciculi, radiating from the base to the apex of each in straight or slightly spiral lines.

Type, *Polymastia mammillaris*, Bowerbank.

This genus is closely allied to *Alcyoncellum*, Quoy et Gaimard; the principal difference being that in the latter the sponge always consists of a single fistula, while in the former it is constructed of a basal mass from which numerous fistulæ emanate. The form and structure of the fistular organs in each genus very closely resemble each other. Beside these structural differences, there are others of a less striking description, that strongly indicate the necessity for generic separation. Thus in *Alcyoncellum corbicula*, in the Museum at Paris, and *Euplectella aspergillum*, Owen, there are an abundance of interstitial spicula of rectangulated hexradiate forms, which are very characteristic of those species, while the British species of *Polymastia* with which we are acquainted appear to be totally destitute of these complicated and beautiful forms of spicula. I have therefore thought it desirable, notwithstanding the close agreement that exists in the structure of their fistulæ, that a generic distinction should be established between them.

Halichondria mammillaris, Johnston, is the best type of the genus *Polymastia*. Tho whole of the parietes of these elongated fistulæ are inhalant. In some specimens of *P. mammillaris* dredged in Vigo Bay by my friend Mr. McAndrew, the open pores are exceedingly numerous, and the exhalant organs are as distinctly shown to be confined to the distal extremities of the fistulæ.

Fig. 358, Plate XXIX, represents a view of a small portion of the side of one of the large cloacæ of *Polymastia robusta*, Bowerbank, exhibiting the structure and mode of disposition of the longitudinal skeleton fasciculi, × 25 linear.

HALYPHYSEMA, *Bowerbank.*

Sponge. Consisting of a hollow basal mass, from which emanates a single cloacal fistula. Skeleton. Spicula of the base disposed irregularly; spicula of the fistula disposed principally in lines parallel to the long axis of the sponge, without fasciculation.

Type, *Halyphysema Tumanowiczii,* Bowerbank.

In its form and habit the type of this genus closely resembles *Polymastia brevis;* but the total absence of fasciculi in its construction at once marks it as a distinct genus, although a closely allied one. The type species, *H. Tumanowiczii,* is remarkable as being the smallest known British sponge; it rarely exceeds a line in height. The base of the sponge resembles in form the half of an orange cut at right angles to its axis, and the fistular cloaca is usually dilated at its distal extremity. I have been unable to detect either oscula or pores in any of the numerous specimens I have examined; but from the general accordance in structure with the genera *Alcyoncellum* and *Polymastia,* there is a strong presumption that the oscula will prove to be congregated at the distal extremity of the cloacal fistula, as in those genera.

Fig. 359, Plate XXX, represents a complete specimen of *Halyphysema Tumanowiczii,* (pronounced Tumanovitchii) based on the stem of a Zoophyte, exhibiting the irregular longitudinal disposition of the skeleton spicula, × 175 linear.

CIOCALYPTA, *Bowerbank.*

Skeleton. Composed of numerous closed columns, each consisting of a central axis of compact, irregularly elongated, reticulated structure, from the surface of

which radiate, at about right angles, numerous short simple cylindrical pedicles, or stout fasciculi of closely packed spicula; the distal ends of each pedestal separating and radiating in numerous curved lines which spread over the inner surface of the dermal membrane, separating and sustaining it at all parts at a considerable distance from the central axis of the skeleton.

Type, *Ciocalypta penicillus*, Bowerbank.

This genus is allied, by its structural peculiarities, to a certain extent, to *Dictyocylindrus*, Bowerbank, *Hyalonema*, Gray, and *Alcyoncellum*, Quoy et Gaimard. The central axial column of the skeleton is composed of elongated stout reticulations of siliceous spicula, closely resembling the corresponding tissues of the axial column of a *Dictyocylindrus;* but the space between the surface of the column and the inner surface of the dermis is not filled, as in that genus, by the usual interstitial structures of the sponge, it is completely and widely separated from the dermis in a manner very similar to that of the structure of the greatly elongated cloacal appendage of *Hyalonema mirabilis*, as it appears in its present condition in the most perfect specimens in the British Museum and in the collection of Dr. Gray. There is this difference between the structures of the two genera. The coriaceous dermis surrounding the beautiful spiral axial column of *Hyalonema* is very thick, and is abundantly furnished with projecting oscula; and it does not present any indications of lateral pedestals, either on its inner surface or on the surface of the axial column, while these organs are abundant in *C. penicillus;* and its dermis also is comparatively thin and delicately reticulated.

The dermal portion of the sponge in *C. penicillus*, and the reticulated tissues on its inner surface, closely resemble the corresponding tissues in *Alcyoncellum* in their structure. The pores, in number, size, and mode of distribution, are very similar to those of *Polymastia robusta*, Bowerbank; but the stratum of these reticulated skeleton structures is not so thick in proportion, and in *Alcyoncellum* and *Poly-*

mastia there is no central axial column. I could not detect interstitial membranes in any part of the space intervening between the axial column and the dermis in *C. pencillus*, but the skeleton column is permeated by numerous interstitial canals.

The structure of the short pedestals passing from the axial column to the inner surface of the dermis is different from that of the axis; the spicula composing them are parallel to each other, and they are firmly packed together. The bases of the pedestals arise from the surface and from within the substance of the central column, with which they appear to have no further connection than that which is necessary to secure them firmly in their respective positions. Their apices present a very beautiful appearance, spreading out towards the inner surface of the dermis in curves, in the direction of angles of about 45 degrees, diverging in every direction over its inner surface, which, when viewed with a microscopic power of about 100 linear, resembles an elaborately and beautifully groined roof of a Gothic crypt where the pedestals impinge.

Fig. 360, Plate XXX, represents a longitudinal section through the central axis of one of the elongate cloacal portions of the sponge, exhibiting the central column and the small cylindrical pedestals or short fasciculi of closely packed spicula, each terminating at the outer surface of the dermis of the sponge, natural size. Fig. 361, exhibits a section of the specimen represented by Fig. 360, at about the middle of the cloacal column, showing the mode of the radiation of the distal ends of the small pedestals on the inner surface of the dermis, $\times$ 25 linear.

TETHEA, *Lamarck*.

The following are the generic characters given by Lamarck, in his 'Anim. sans Vert.' 2nd edit. ii. 384:—

"Téthie (*Tethea*).

"Polypier tubéreux, subglobuleux, très fibreux intérieurement; à fibre subfasciculées, divergentes ou rayonnantes de l'intérieur à la circonférence et agglutinées entre elles par un peu de pulpe; à cellule dans un encroûtement cortical quelquefois caduc. Les oscules rarement perceptibles."

Dr. Johnston's version of the generic characters differs slightly from Lamarck's. They are as follows:—

"Sponge tuberous, suborbicular, solid and compact, invested with a distinct rind or skin, the interior sarcoid loaded with crystalline spicula collected into bundles and radiating from a more compact nucleus to the circumference. Marine."

It is much easier to find faults in the generic characters of both the authors quoted, than it is to improve them. The extreme simplicity of the structural characters of *Tethea* is a strong temptation to endeavour to multiply them; but in doing so, Dr. Johnston has introduced two—the structure of the dermal portion of the sponges, and the tuberous nature of its surface—which are not common to all the known species. If we consider the word "tuberous" in the usual English acceptation of the word, as a body "full of knobs or swellings," then very few or perhaps none of the species of *Tethea* would, in their natural condition, exhibit this character, but all of them would be in a greater or less degree subglobular. Dr. Johnstone's description of *Tethea* was founded on the structure of *T. lyncurium* only, and in this species the "thick rind" is very distinctly to be seen, but in other species this structure is totally wanting. It therefore ceases to be of value as a generic character, and becomes a specific one only. Under these circumstances I propose the following modification of the previously published generic characters:—

Sponge massive, suborbicular. Skeleton consisting of fasciculi of spicula. Fasciculi radiating from a basal or excentrical point to the surface. Intermarginal cavities unsymmetrical, confluent. Propagation by internal or external gemmulation.

Types, *Tethea lyncurium*, Linnæus, &c.
„ *cranium*, Lamarck.

This genus affords us one of the few instances in which we may avail ourselves of external form as a generic character; but even in *Tethea* we approach exceptions to the rule in the depressed form of *T. Collingsii,* Bowerbank, as exhibited in the only perfect specimen of that species which I have seen, and in the still more depressed form of *T. spinularia,* Bowerbank.

Although the skeleton structures in the species of this genus differ to an exceedingly slight extent, the subsidiary spicula vary exceedingly in the different species. In some, ternate spicula are numerous, and in others they are entirely absent, and stellate forms of spicula occur in many varieties of form.

The sponges of this genus appear to be highly organized. Audouin and Milne-Edwards saw the oscula open and the excurrent streams in action, and I have seen the same myself in a specimen of *T. lyncurium.* My friend Mr. George Clifton, of Freemantle, Western Australia, in a letter dated 25th January, 1861, writes, "I have sent you several fine specimens of *Tethea.* When these animals are first taken out of the water they are of a brilliant orange colour, and commence squirting water from the oscula situated on the centre of the upper surface; they also contract considerably, but on being replaced in their native element they regain their natural size and reabsorb water."

The mode of propagation varies in different species. In *T. cranium* and *simillima,* Bowerbank, MS., it is by internal gemmulation, in *T. lyncurium* by external gemmulation, and in some other species the mode is not apparent.

Figure 362, Plate XXXI, represents a portion of a slice at right angles to the surface, from *Tethia cranium,* showing

the fasciculi of defensive spicula (*a*) and the mode in which they are supported by buttresses of spicula beneath the surface of the sponge at *b*; *c*, the recurvo-ternate spicula, × 50 linear.

HALICNEMIA, *Bowerbank.*

Skeleton formed of a single superior stratum of spicula radiating from the centre to the circumference of the sponge at about its middle, and of an inferior stratum of spicula distributed without order.

Type, *Halicnemia patera*, Bowerbank.

The nearest alliance to this genus appears to be *Tethea*, in which the skeleton is formed of numerous fasciculi of spicula radiating from the centre to all parts of a spherical or elliptical mass; while in *Halicnemia* the radiating fasciculi are confined to a common plane, beneath which there is a second stratum of spicula, which fills the space beneath the radial stratum and the lower surface of the sponge, but without being disposed in order; and the spicula of the inferior stratum differ materially in form and proportions from those of the superior one.

In all the specimens of this genus that I have seen there is a small pebble imbedded in the centre of each sponge, from the surface of which the basal fasciculi of the radial series emanate; but although this appears to be the established habit of this species, it is advisable not to consider it as a generic character, although it may eventually prove to be that the pebble is as much a portion of the skeleton of the animal as the grains of extraneous matter which are taken up by and become imbedded in the keratose fibres of the genus *Dysidea*. Fig. 363, Plate XXXII, represents a portion of a section at right angles to the surface of the sponge, exhibiting the mode of disposition of the spicula of the skeleton × 25 linear. Fig. 364 is a view

of a portion of the same section taken at *a*, fig. 363, × 108 linear.

DICTYOCYLINDRUS, *Bowerbank.*

Skeleton. Without fibre. Composed of a loosely compacted columnar axis of spicula, disposed principally in the direction of the line of the axial column, from which a peripheral system of long single or fasciculated defensive spicula radiate at right angles to the axial column.

Type, *Dictyocylindrus hispidus*, Bowerbank.

Halichondria hispida, Johnston, and *Spongia stuposa*, var. *damicornis*, Montagu, are excellent types of the peculiar mode of arrangement of the spicula which characterises this genus. The skeleton consists of a central column of large elongate spicula, disposed principally in the line of the axis of the sponge and at a slight angle to it, approaching in form an irregular cylinder of network of elongated meshes, rarely exhibiting an appearance of horny fibre, but formed for the most part of spicula cemented together near their terminations. Towards the base of the sponge the horny substance surrounding the spicula is sometimes so thick as to simulate a proper horny fibre; but if it be carefully traced, it will always be found to be dependent on the spicula; where their course is abruptly terminated the horny structure also terminates; whereas in true horny fibrous structures which contain spicula the course of the fibre is continuous and uniform whether the spicula be present or deficient, and in the newly produced fibre the latter is generally the case.

The structure of the skeleton in this genus differs from that of *Halichondria oculata*, Johnston, (*Chalina oculata*, Bowerbank), in the regularly elongate disposition of the spicula of the skeleton; and the spicula are necessarily very much larger and longer than those included in the

close fibrous network of *C. oculata;* and it is still further removed from the horny fibrous structure of *Halichondria cervicornis,* Johnston, 'Hist. Brit. Sponges,' pl. iv. The axial column of this genus differs strikingly from that of the strong, closely packed axis of *Ecionemia,* and the peripheral system of spicula are never furnished with ternate connecting spicula. All the species of this genus I have hitherto seen are more or less ramous in form. Fig. 365, Plate XXXII, represents part of a small branch of *Dictyocylindrus rugosus,* Bowerbank, exhibiting the radiating structure of the defensive fasciculi, × 50 linear; *a,* part of the central axis of spicula. Fig. 366, Plate XXXIII, represents part of a section through the axial column of *Dictyocylindrus ramosus,* showing the elongo-reticulate structure of the skeleton of the sponge, × 50 linear.

PHAKELLIA, *Bowerbank.*

Skeleton. Composed of a multitude of primary cylindrical axes, radiating from a common base and ramifying continuously, from which emanate at about right angles to the axes a secondary series of ramuli, which ramify continuously as they progress towards the surface, but never appear to anastomose.

Type, *Phakellia ventilabrum,* Bowerbank.

I know of no other species, either British or foreign, that possesses the peculiar conformation that distinguishes the sponge that is the type of this genus. The primary cylindrical axes very closely resemble those of *Dictyocylindrus,* but in that genus the spicula radiating from the axes are separate and distinct, each having its proximal end based on the primary cylinders of the skeleton, and its distal one reaching nearly to, or passing through the dermal membrane of the sponge; or if they be fasciculated, the fasciculi are simply plumose, and in no case with which I am acquainted at all ramulous. In *Phakellia* the secondary skeleton is formed of distinct slender branches, each

composed of numerous spicula ramifying continuously, and each ramulus increases in size and the number of its spicula as it approaches the surface of the sponge. Single spicula are frequently projected from the ramuli in an ascending direction at an angle of a few degrees, and at their distal terminations at the surface of the sponge; the whole of the terminal spicula radiate more or less at angles from their axial line, and passing through the dermal membrane form the external defences of the sponge. Although constantly ramifying and freely intermingling, I have never detected them anastomosing. The term *Phakellia* is applicable to both the primary and secondary ramifications of the skeleton. The type of this genus is *Halichondria ventilabrum*, Johnston. I have not yet met with an exotic species of the genus. Fig. 367, Plate XXXIII, represents a longitudinal section of one of the primary radial lines of the skeleton structure, exhibiting the slender secondary radiations of the skeleton; *a*, part of the primary axial portion of the skeleton; *b*, dermal membrane, × 50 linear.

The genera *Microciona*, *Hymeraphia*, and *Hymedesmia* form a group essentially different in structural character from the other genera of the Spongiadæ; but they are closely allied to each other by the peculiar characters of their basal membranes in conjunction with the other parts of the skeleton. From the nature of their structures, the species generally assume a thin coating form and are often very minute.

In most of the genera of Spongiadæ the basal membrane of the sponge ceases to be of marked importance after the earliest stages of its development, but in these genera it continues throughout the whole existence of the sponge to form an important part of its skeleton structure. It is a common base whence spring the whole of the other component parts of the skeleton; and its importance is further indicated by its also being the common base in some species of the internal as well as the external defensive spicula of the sponges in which those organs occur.

MICROCIONA, *Bowerbank.*

Skeleton. A common basal membrane, whence spring at or about right angles to its plane numerous separate columns of spicula intermixed with keratode, furnished externally with spicula which radiate from the columns at various angles towards the dermal surface of the sponge.

Type, *Microciona atrasanguinea,* Bowerbank.

The skeleton of the type of this genus, *M. atrasanguinea,* is different from that of any other genus of sponges that I have hitherto seen. It consists of numerous, nearly equidistant, short, straight, separate columns of spicula and keratode from all parts of the sides of which spring stout, long, curved, fusiformi-attenuato-subspinulate spicula, the convex side of each spiculum being outward, and each column terminates with five or six of these spicula disposed in the same manner and at the same angle to the axial line of the column, that is from about twenty to forty-five degrees. The proportions of the skeleton-columns vary in different species. In *M. atrasanguinea* they are short, stout, and exceedingly well defined. In *M. ambigua* they are short and indistinctly produced, and in *M. carnosa* they are long, slender, flexuous, and frequently branched; but however they may vary in their proportions in different species, their normal character, both as regards structure and position in the sponge, is always preserved. Fig. 368, Plate XXXIII, represents a single column of the skeleton of *Microciona atrasanguinea,* Bowerbank, showing its structure and the proportions and positions of the external defensive spicula, × 175 linear. Fig. 369, Plate XXXIV, represents a section at right angles to the surface of the sponge exhibiting the columns of the skeleton *in situ; a,* the plane of the dermal membrane with groups of tension spicula.

Genus—Hymeraphia, *Bowerbank.*

Skeleton. A single basal membrane, whence spring numerous large separate spicula, which pass through the entire thickness of the sarcodous stratum to, or beyond the dermal surface of the sponge.

Type, *Hymeraphia stellifera*, Bowerbank.

This genus is nearly allied to *Microciona*, but is more simple in its structure; as in place of the columns of the skeleton compounded of keratode and spicula cemented together, and emanating from a common basal membrane as in the latter genus, we find single spicula only, devoid of keratode and based on a common membrane, whence they pass through the entire substance of the sponge; and in all the species at present known, they penetrate the dermal membrane and project beyond its surface to a considerable extent, thus combining the two offices of skeleton and external defensive spicula. These organs are therefore, as compared with the skeleton spicula of other members of the Spongiadæ, and to the entire mass of the sponges to which they belong, of exceedingly robust proportions; their length being frequently twice that of the entire thickness of the sponge.

These peculiarities of structure indicate a common habit of extreme thinness in the species, and such is in reality the condition of those with which we are acquainted. Fig. 370, Plate XXXIV, represents a section of *Hymeraphia stellifera*, Bowerbank, showing the large bulbous skeleton spicula *in situ*, their apices forming the external defences; *a*, the stelliferous internal defensive spicula elevated by a grain of sand beneath the basal membrane, $\times$ 108 linear. Fig. 34, Plate I, exhibits one of the stelliferous defensive spicula, $\times$ 260 linear.

HYMEDESMIA, *Bowerbank.*

Skeleton. A common basal membrane sustaining a thin stratum of disjoined fasciculi of spicula.

Type, *Hymedesmia Zetlandica*, Bowerbank.

The species on which this genus is founded very closely resembles in habit and general appearance those of the genera *Microciona* and *Hymeraphia*, and in regard to the special offices of the basal membrane, it assimilates with them completely. But it differs from them, inasmuch as the spicular portions of the skeleton do not emanate immediately from the basal membrane, but are recumbent on it in the form of disjoined fasciculi of spicula. But although different from them in this important respect, the close alliance with them is indicated by the common habit of the possession by the basal membrane of the whole, or nearly so, of the defensive spicula of the sponge; indicating the common property of extreme thinness of structure which exists in these genera.

The free condition of the fasciculi of the skeleton connects this genus in some degree with the Halichondroid genera of sponges, but there are none of the species of those genera in which the fasciculi of the skeleton are separate from each other. The nearest allied genus in that direction appears to be *Hymeniacidon*. Fig. 371, Plate XXXV, exhibits the disjoined fasciculi of the skeleton *in situ*, in *Hymedesmia Zetlandica*, × 108 linear; and Fig. 296 Plate XVIII, represents a small portion of the inner surface of the dermal membrane of the same sponge, showing the fasciculation of the simple bihamate spicula, the equi-anchorate ones dispersed singly on the membranes, and the large attenuato-acuate entirely spined defensive ones *in situ*, × 308 linear.

Suborder II. Spiculo-membranous skeletons. Composed of interstitial membranes, having the skeleton spicula irregularly dispersed on their surfaces.

The prominent character of this Order is that the spicula of the sponges composing it do not assume either the radiate, fasciculate, or reticulate structural arrangement. The distribution of the spicula on the interstitial membranes being without any approximation to order.

HYMENIACIDON, *Bowerbank*.

Skeleton without fibre, spicula without order, imbedded in irregularly disposed membranous structure.

Type, *Hymeniacidon caruncula*, Bowerbank.

In *Hymeniacidon* the spicula are subordinate to the membranous structure, they follow its course and are imbedded without order on its surface. The contrary is the case in *Halichondria*. The network of spicula in that genus, although irregular, is decidedly the predominant structure, and the membranous tissues are secondary to it, and exist only as interstitial organs. The larger and stouter of the spicula in *Hymeniacidon*, although dispersed amid the slender ones, may be considered as the representative of the skeleton spicula, while the slender ones are truly those of the membranes, the tension ones.

In some species the interstitial tissues are constructed diffusely, as in *H. caruncula*, while in other species, as in *H. suberea* (*Halichondria suberea*, Johnston) and a few other closely allied species, they are more than usually compact, so that in the dried state the texture of these sponges are very like that of fine hard cork. From this peculiarity of their appearance in the dried condition, and the exceeding compactness of their structure, I was formerly inclined to believe them to be generically different from the

great mass of the species of *Hymeniacidon*, and I accordingly inserted them in the list of British sponges, published in the "Report of the Dredging Committee" in 'the Reports of the British Association' for 1860, under the titles of *Halina suberea, ficus*, &c.; but a closer examination of their internal structure has convinced me that their only real difference from the other species of *Hymeniacidon* is in their greater compactness of skeleton structure, and I have accordingly removed those species to the genus *Hymeniacidon*.

In the greater number of the species of this genus the tension spicula are of the same form as those of the skeleton, and are only to be distinguished from them by their greater degree of tenuity, but in a few of the known species they are different both in size and form.

The mode of propagation in all the species in which I have found the reproductive organs, appears to be by internal gemmulation. In *H. carnosa* and several other species of the genus they are simple, spherical, aspiculous, membranous vesicles, filled with round or oval vesicular molecules. The genus *Halisarca*, Dujardin, was supposed by both that author and Dr. Johnston to be entirely destitute of spicula; but I have, since the publication of the 'History of the British Sponges,' found them in *H. Dujardinii* in abundance. They are so minute and so completely obscured by the surrounding sarcode, that they can rarely be detected in either the living or the dead specimens when examined in water; but if a portion of the sponge be dried on a slip of glass and covered with Canada balsam, they may be detected by transmitted light and a power of 400 linear in considerable numbers, dispersed on the interstitial membranes of the sponge. This genus will therefore merge in that of *Hymeniacidon*, with which it agrees in every structural peculiarity. Fig. 372, Plate XXXV, exhibits the dispersed condition of the skeleton spicula on the interstitial membranes of a specimen of *Hymeniacidon caruncula*, × 108 linear.

Suborder III. Spiculo-reticulate skeletons. Skeletons continuously reticulate in structure, but not fibrous.

Halichondria.
Hyalonema.
Isodictya.
Spongilla.

The sponges of this suborder vary in the different genera to a great extent in the mode of the construction of the skeleton, but in all cases the spicula are the dominant material; their terminations overlap each other, and they are cemented together by keratode. The reticulations thus formed sometimes consist of a single series of spicula, at other times they are very numerous, and are crowded together in the manner of elongated fasciculi.

The genera *Halichondria* and *Isodictya* are exceedingly rich in species, but the inconvenience attending their discrimination arising from their number may be remedied to a great extent hereafter by subdivisions of each genus, based on the characteristic forms of the spicula of their respective skeletons. The structural distinction between *Halichondria* and *Isodictya* is so well marked as to render the recognition of each comparatively certain and easy. The skeletons of the species of the latter genus, generally speaking, are very much more slight and fragile than those of the former one, and the same rule obtains to a great extent as regards the comparative size of their spicula, and in many species of *Isodictya* they are very minute. *Hyalonema* and *Spongilla* are readily to be distinguished by the peculiarities of their structure and localities.

The genus *Halichondria*, as constituted by Dr. Fleming in his 'History of British Animals,' and adopted by Dr. Johnston in his 'History of British Sponges,' contains species which differ exceedingly in their mode of organization. Thus, if we take *H. panicea* of Johnston, which is undoubtedly the "sponge-like crumb of bread" of Ellis,

and the older authors, and therefore the proper type of the genus, we find the skeleton destitute of fibre, but composed of an irregular network of spicula cemented together at their apices by keratode. If we examine the well-known branching sponge so common on all our coasts, *Halichondria oculata* of the same author, we find an abundance of keratose fibre containing spicula deeply imbedded in its substance, but not necessarily uniting at their apices, and the network of the skeleton is not irregular as in the first instance, but on the contrary is more or less symmetrically disposed in all parts of the sponge. If we take *Halichondria suberea* of the same authors we find neither network of spicula nor a keratose fibrous structure, but apparently an amorphous sarcoid mass containing spicula and membranes, on which the former are dispersed without any order or connection. As we extend our researches among the other British species of Fleming's genus *Halichondria*, other striking and permanent variations in the arrangement of their skeleton tissues present themselves. Their great differences in structure therefore afford ample grounds for the division of the species comprehended under *Halichondria* as constituted by Fleming into a series of genera, having each for its base a separate type of organization; and as the variations in structural character, some of which are mentioned above, are both numerous and strikingly characteristic, I propose to limit the genus *Halichondria* to those species only, which agree in their organization with *H. panicea* of Johnston, and to distribute the remaining species in other genera, the distinctive characters being in all cases based primarily on the different modes of the organization of the skeleton of the animal, and when necessary taking in aid such other organic characters as may be found available for the purpose of accurate discrimination. I therefore propose to limit the genus *Halichondria* to those sponges only, that exhibit the following characters.

HALICHONDRIA, *Fleming.*

Sponge. Skeleton without fibre; composed of an irregular polyserial network of spicula cemented together by keratode.

Type, *Halichondria panicea,* Johnston.

The anatomical structure of the group included under this genus is distinct and unmistakeable. There is no fibre whatever, the skeleton being formed of spicula collected into bundles of a greater or less number cemented together by keratode, but which substance does not extend beyond the space occupied by the respective bundles; and when parts of the reticulated skeleton are formed of single series of spicula only, they are simply cemented together at their points, and the reticulated skeleton thus formed has no definite arrangement.

In some species of the genus the reticular character of the skeleton is much more distinct than in others. *H. panicea,* although the type of the genus is by no means the best specimen of its character. Fig. 300, Plate XIX, represents a section of *H. panicea* at right angles to its surface, and Fig. 303, the reticulations supporting the dermal membrane, × 108 linear. Fig. 373, Plate XXXV, represents a section at right angles to the surface of a specimen of *Halichondria incrustans,* Johnston, × 50 linear, a better type of the structural character of the genus than *H. panicea.*

HYALONEMA, *Gray.*

Dr. Gray has characterised this genus in his descriptions of genera of Axiform Zoophites, or Barked Corals, as "coral subcylindrical, rather attenuated, and immersed in a fixed sponge. Axis in the form of numerous elongated, slender, filiform, siliceous fibres, extending from end to end

of the coral, and slightly twisted together like a rope. Bark fleshy, granular, strengthened with short cylindrical spicula. Polypiferous cells scattered, rather produced, wart-like, with a flat radiated tip." ('Proceedings of the Zoological Society of London' for 1857, page 279.) This description applies only to the singular cloacal appendage to the sponge from amidst which it springs, the structure of the body of the animal being evidently considered by the author as an extraneous mass. The basal sponge is undoubtedly a portion of the animal to which the part described by Dr. Gray belongs, the spicula of the elongated cloacal portion being also abundant in the basal mass of sponge; and the basal mass of the specimen described by Dr. Gray is identical in its structural character with that of the specimen of *Hyalonema mirabilis* in the Bristol Museum. It becomes necessary therefore to remodel the generic characters so as to embrace the leading distinctive structures of the skeleton of the animal, and I propose the following form of description:

Skeleton an indefinite network of siliceous spicula, composed of separated elongated fasciculi, reposing on continuous membranes, having the middle of the sponge perforated vertically by an extended spiral fasciculus of single, elongated, and very large spicula, forming the axial skeleton of a columnar cloacal system.

Type, *Hyalonema mirabilis*, Gray.

The construction of the skeleton of the mass of the sponge is intermediate between that of *Halichondria panicea* and *Hymeniacidon caruncula*, the respective types of those genera. The network of fasciculated spicula appears never to be definite and continuous as in the former, nor are the skeleton spicula in a dispersed condition on the continuous membranes as in the latter, but are gathered into elongated fasciculi which cross each other in the same plane in every imaginable direction, but without ever appearing to anastomose. The fasciculi vary exceedingly in the

number of spicula of which their diameter is formed, sometimes consisting of two or three spicula only, and at other times of more than it is possible to count. They often divide, the branches passing in different directions, but they never reunite or anastomose with other fasciculi. A portion of this network of spicula is represented by Fig. 375, Plate XXXV. The columnar axis of the cloacal system consists of one large spiral fasciculus of spicula, each of which extends from the base or very near that part of the sponge, to near or quite to the apex of the column, the direction of the spiral being from right to left. Fig. 374, Plate XXXV, represents a portion of the great cloacal column, exhibiting part of the spiral axial fasciculus surrounded by the remains of its dermal coat, with numerous oscula projecting from its surface, copied from 'Zoological Proceedings' for 1857.

There is a close approximate alliance to this form of the cloacal appendage of *Hyalonema* in the corresponding organs of the British genus *Ciocalypta*, Bowerbank.

ISODICTYA, *Bowerbank.*

SPONGIA, *Montagu.*
HALICHONDRIA, *Fleming.*
HALICHONDRIA, *Johnston.*

Skeleton without fibre; composed of a symmetrical network of spicula; the primary lines of the skeleton passing from the base or centre to the surface, and the secondary lines disposed at about right angles to the primary ones. Propagation by internal, membranaceous, aspiculous gemmules.

Types, *Isodictya palmata* and *Normani*, Bowerbank.

This genus, in the structure and arrangement of its skeleton, is intermediate between *Halichondria* and *Chalina*, as defined in the present work. Like the former, the spicula of the network composing the skeleton are merely cemented together, not inclosed within a regular horny

fibre; but the disposition of the network is not entirely irregular, but like that of the latter genus, more or less composed of a primary series of lines radiating from the axis or base of the sponge, and of secondary series connecting the primary ones at about right angles to them; in fact simulating very closely the arrangement of the skeleton of *Chalina oculata*, but without the keratose fibre surrounding the spicula of the skeleton in that sponge.

In some of the species of this genus the symmetrical arrangement of the lines of the skeleton is distinct only near the surface of the sponge, while in the more deeply seated parts, the irregular characters of a *Halichondria* is simulated. In determining the species of this genus, the sponge requires to be carefully examined by sections at right angles to the surface, where the distinctive character rarely fails to be readily detected. On the contrary, in *Halichondria panicea*, the type of that genus, I have never succeeded in finding such a linear arrangement of the skeleton as marks that of *Isodictya*. In a hasty examination a single linear series of spicula will therefore often prove an excellent guide to the discrimination of this genus.

In most of the species with which I am acquainted there is a generally prevailing character of fragility; the primary lines being composed of very few spicula, while the secondary ones, are most frequently unispicular. Most of the species are thin, coating or encrusting sponges, and rarely appear to rise in tuberous masses, as the numerous species of *Halichondria* are in the habit of doing.

Isodictya infundibuliformis is perhaps the most perfect type of the genus, as in it we have the primary and secondary lines of the skeleton distinctly separated by the difference in the form of their spicula. In some species of the genus, as in *I. simulo*, the cementing keratode of the skeleton is so abundant in some parts as to cause it to simulate very closely the structure of a *Chalina*, but the irregularity and compressed form of this pseudo-fibre is readily to be distinguished from true keratose fibre by a careful observer. In other species, as in *I. mammeata*, the sarcode surrounding

the skeleton is so abundant as to cause it to simulate a delicate form of *Chalina*, but on immersion in Canada balsam the fibre-like form disappears, the sarcode contracting into a mere granulated coating, and the skeleton assumes the normal appearance of *Isodictya*. Fig. 376, Plate XXXVI, represents a section at right angles to the surface from *Isodictya Normani*, exhibiting the regular and nearly rectangular structure of the network of the skeleton, × 108 linear.

SPONGILLA, *Linnæus*, *Lamarck*, and *Johnston*.

HALICHONDRIA, *Fleming*.

The structural peculiarities of the skeleton of *Spongilla* are the same as those of *Isodictya*, and if there had not existed a striking distinctive difference in their reproductive organs the two genera must have been united. Under these circumstances I propose the following as the characters of the genus *Spongilla*.

Skeleton without fibre, composed of a symmetrical network of spicula; the primary lines of the skeleton passing from the base or centre to the surface, and the secondary lines disposed at about right angles to the primary ones. Reproductive organs, ovaries, coriaceous and abundantly spiculous.

Type, *Spongilla fluviatilis*, Linnæus.

All the species are inhabitants of fresh water. As an illustration of the form of the skeleton in this genus, see the figure of that of *Isodictya Normani*, Fig. 376, Plate XXXVI.

In some species from the River Amazon, the skeleton fibre is so abundantly spiculous as to cause it closely to simulate that of a *Desmacidon*; but a careful observation of the more slender portions of the skeleton will dispel this illusion.

Suborder IV. Spiculo-fibrous skeletons. Regularly fibrous. Fibres filled with spicula.

Desmacidon.
Raphyrus.

The spiculo-fibrous skeletons differ from the fibro-spicular ones in this respect. In the first the form and proportions of the fibre are dependent on the greater or the less development of spicula, and the keratode serves only as a cementing and coating material. In the latter the keratode is the primary agent in the formation of the fibre, and the spicula the secondary or auxiliary agent only.

DESMACIDON, *Bowerbank.*

HALICHONDRIA, *Johnston.*

Skeleton fibrous, irregularly reticulated. Fibres composed entirely of spicula arranged in accordance with the axis of the fibre, cemented together and thinly coated with keratode.

Type, *Desmacidon fruticosa,* Bowerbank.

The structure of the skeleton fibre in this genus readily distinguishes it from all others. The form and size of the tissue is entirely dependent on the greater or less quantity of spicula present; the keratode serving only as a cementing and coating material. *Halichondria ægagropila* and *fruticosa,* Johnston, are the only two British species of the genus known. Fig. 264, Plate XIII, represents a fibre from the skeleton of *Halichondria ægagropila*, Johnston, illustrating the structure of multispiculated keratose fibre, × 108.

RAPHYRUS, *Bowerbank.*

Skeleton fibrous, but not horny. Fibre composed of a dense mass of siliceous spicula mixed together without order.

The structure of this genus is singular. The fibre in the only species with which I am acquainted, *Raphyrus Griffithsii,* is comparatively very coarse, frequently attaining the size of a line in diameter near the anastomosing parts, or expanding into a broad plate-like form. The spicula composing it are closely thrown together without any approach to the longitudinal disposition which prevails in the skeleton of *Desmacidon.* The same absence of definite arrangement obtains in the interstitial membranes, which have precisely the mode of structure which characterises the genus *Hymeniacidon,* which has "spicula without order, imbedded in irregularly disposed membranous structure."

Fig. 265, Plate XIII, represents a longitudinal section of a small fibre of the skeleton of *Raphyrus Griffithsii,* Bowerbank, showing the irregular disposition of the spicula within it, × 90 linear.

Suborder V. Compound reticulate skeletons, having the primary reticulations fibro-spiculate, and the interstices filled with a secondary spiculo-reticulate skeleton.

Diplodemia, Bowerbank.

This Order forms a connecting structural link between the Orders Silicea and Keratosa. The structure of the keratose fibre would indicate its place to be in the third suborder of the latter, but the presence of the Halichondroid secondary skeleton in such force, in conjunction with the irregular spiculated structure of the kerato-fibrous primary skeleton, has induced me to place it among the

Silicea. For more minute information regarding its structural peculiarities, I must refer my readers to the following description of the generic characters of *Diplodemia*.

DIPLODEMIA, *Bowerbank*.

Skeleton fibrous. Fibres keratose, hetro-spiculous; combined with a secondary skeleton of irregular network of spicula; rete unispiculate, rarely bispiculate. Ovaries membranous and spiculous.

Type, *Diplodemia vesicula*, Bowerbank.

The fibres in the skeleton of the only known species in this genus are very remarkable. They are smooth and cylindrical, having an axial line of, generally speaking, single spicula united at their points, running throughout the whole length of the fibre. But when it is of more than ordinary diameter, there are frequently other spicula at intervals imbedded in the fibre parallel to the axial series. Throughout the whole length of the fibres, at short intervals, there are similar spicula to the axial ones, imbedded at right angles to the axis of the fibre, frequently projecting from the surface for half, or more than half their length. Some of these projecting spicula originate small lateral branches of the keratose skeleton, but by far the greater portion of them are the connecting points of the keratose fibres and the reticulo-spiculate secondary skeleton; the former being thus completely imbedded amidst the latter.

The structure of the ovaria in this genus is also peculiar to it. The wall is very thin, and appears to consist of a single membrane profusely furnished with spicula which cross each other in every direction, and occasionally appear to assume a somewhat fasciculated arrangement. They are not uniform in shape, some being regularly oval, while others are more or less ovoid.

But one species of this singular genus is known, *D. vesicula*, Bowerbank, from deep water at Shetland. Fig.

273, Plate XIV, represents a single hetro-spiculous fibre of the skeleton, × 175 linear. Fig. 377, Plate XXXVI, a portion of the fibrous skeleton with the uni-spiculate secondary skeleton, × 108 linear; and Fig. 234, Plate XXIII, a perfect ovarium of *D. vesiculata*, Bowerbank, and a portion of a second one showing the interior and the thickness of its walls in its natural state, × 83 linear.

Suborder VI. Solid siliceo-fibrous skeletons. Skeletons reticulate. Fibres composed of concentric layers of solid silex, without a central canal. Reticulations unsymmetrical.

Dactylocalyx, Stutchbury (*Iphiteon*, French Museum).

The structure and mode of growth in this suborder of siliceo-fibrous sponges appears to be precisely the same as that of the kerato-fibrous sponges of the first suborder of the third order Keratosa.

Dactylocalyx pumicea, Stutchbury, was described in the 'Proceedings of the Zoological Society,' part 9, 1841, p. 86, October 26, 1841. The author describes it thus: "Sponge fixed, siliceous; incurrent canals uniform in size; excurrent canals large, forming deep sinuosities on the outer surface, radiating from the root to the outer circumference."

The sponge was received by the Bristol Museum from Dr. Cutting of Barbadoes.

The genus *Dactylocalyx* was established by Mr. Stutchbury to designate this fine siliceo-fibrous sponge. Half of the type specimen is in the Museum at Bristol, and the remaining portion in the possession of Dr. J. E. Gray of the British Museum. Although the sponge was designated *Dactylocalyx pumicea*, no generic characters were given. I propose therefore to characterise it as follows:

DACTYLOCALYX.

Skeleton siliceo-fibrous. Fibres solid, cylindrical. Reticulations unsymmetrical.

Type, *Dactylocalyx pumicea*, Stutchbury.

Fig. 274, Plate XV, represents the smooth variety of fibre, with young fibres pullulating from the adult ones at (*a*). From the skeleton of *McAndrewsia azoica*, Gray, × 175 linear.

Fig. 275, represents a portion of tuberculated siliceous fibre from the skeleton of *D. pumicea*, Stutchbury, × 108 linear.

Fig. 276, exhibits very prominently tuberculated fibre from *D. Prattii*, Bowerbank, MS.

Fig. 340, Plate XXV, represents a small portion of the skeleton of *Iphiteon panicea* in the Museum of the Jardin des Plantes, Paris, with gemmules *in situ*, × 183 (*Dactylocalyx*, Stutchbury).

Fig. 341, a gemmule detatched from *Iphiteon panicea*, × 666 linear.

Suborder VII. Canaliculated siliceo-fibrous skeletons. Skeletons reticulate, symmetrical. Fibres composed of concentric layers of solid silex, with a continuous central canal.

Type, *Farrea occa*, Bowerbank, MS.

I have seen in the organic remains from deep sea soundings several varieties of fragments of siliceous fibres with simple central canals, having every appearance of being from unknown species of siliceo-fibrous sponges; but the only satisfactory specimen of this genus of sponges is the one at the base of Dr. Arthur Farre's specimen of *Euplectella cucumer*, Owen, described in the 'Transactions of

the Linnean Society of London,' vol. xxii, p. 117, plate xxi.

The fibres in *Farrea occa* are rather coarse, abundantly tuberculated, and the mode of reticulation is rectangular. Their construction is exactly like those of *Verongia*, the type of the fourth suborder of the third order, Keratosa. Fig. 277, Plate XV, represents one of the simple fistulose spiculated fibres from the skeleton of *Farrea occa*, Bowerbank, MS., × 108 linear.

Order III. KERATOSA.

Suborder I. Solid non-spiculate kerato-fibrous skeletons.

The greater number of the sponges of commerce belong to this suborder. How many species are comprised under the designation of "the sponges of commerce" it is very difficult to decide, as we rarely obtain them in their natural condition, but it is certain, from their well-washed skeletons, that their number is considerable, and that at least two distinct genera occur among them. If we assume that the well-known cup-shaped sponge, usually sold as the best Turkey sponge, is the one entitled to the designation of *Spongia officinalis*, we shall then have the type of the first suborder of the third order Keratosa distinguished by the above characters. There are two genera belonging to this suborder; the first of these is *Spongia*, Linnæus. Its character is as follows:

SPONGIA, *Linnæus.*

Skeleton kerato-fibrous. Fibre solid, cylindrical, aspiculous. Rete unsymmetrical.

Type, *Spongia officinalis*, Linnæus.

The number of species of *Spongia* appear to be very considerable, and in all of them the irregular meandering

character of the skeleton fibre readily serves to distinguish them. Fig. 379, Plate XXXVII, exhibits the irregularity of the disposition of the keratose fibres from one of the best Turkey sponges of commerce, × 50 linear, and Fig. 261, Plate XIII, a fibre from a similar description of sponge, from a specimen preserved in spirit in the condition in which it came from the sea, × 175 linear.

The second genus is founded on the specimen described by Sowerby in the 'British Miscellany,' p. 87, plate xlviii, and named by him *Spongia pulchella*. I fortunately have this specimen, and on carefully examining it I find it to possess all the characters of the genus *Spongia*, excepting that the reticulations of the skeleton are very symmetrical, and this is so important a structural difference that I have thought it advisable to constitute it the type of a new genus the characters of which are as follows:

SPONGIONELLA, *Bowerbank*.

SPONGIA, *Sowerby* and *Johnston*.

Skeleton kerato-fibrous. Fibres solid, cylindrical, aspiculous. Rete symmetrical; primary fibres radiating from the base to the apex. Secondary fibres disposed at nearly right angles to the primary ones.

Type, *Spongionella pulchella*, Bowerbank.

Fig. 380, Plate XXXVII, represents a section at right angles to the surface from the type specimen *Spongia pulchella*, Sowerby, showing the nearly regular rectangular mode of disposition of the primary and secondary fibres of the skeleton, × 50 linear.

Suborder II. Solid, semispiculate, kerato-fibrous skeletons.

The sponges of this suborder closely resemble in general appearance those of the genus *Spongia*, but they differ very

considerably in the structural characters of their skeletons, which consist of a somewhat irregular radiation of primary fibres from the base towards the apex of the sponge, with an unsymmetrical series of secondary fibres emanating from and connecting together the series of primary ones.

The primary fibres are compressed and broad in their form, frequently three or four times the width of the diameter of the surrounding cylindrical secondary ones. But their most striking character is their possessing a considerable number of siliceous spicula, which are irregularly imbedded in their centres; sometimes the series of spicula within the fibre consists of but one or two beside each other, and at other times they are numerous and very irregularly disposed. This central series of spicula appears to exist only in the primary fibres, and I have never been able to detect the slightest indication of their presence in any of the secondary series. I first described these structural peculiarities in a paper read before the Microscopical Society of London, January 27, 1841, and it is published in vol. i, p. 32, plate iii of their 'Transactions.'

I have met with numerous instances of the occurrence of this structural arrangement of the skeleton in sponges from Australia and the Mediterranean, but their well-washed condition has left them with but very few capabilities for specific distinction.

I propose to adopt De Blainville's name, *Halispongia*, to designate this genus, the characters of which are as follows:

HALISPONGIA, *De Blainville.*

Skeleton kerato-fibrous. Fibres solid; primary fibres compressed, containing an irregularly disposed series of spicula. Secondary series of fibres unsymmetrical, cylindrical, without spicula.

Fig. 278, Plate XXXVI; represents one of the large primary keratose fibres containing siliceous spicula, and the irregular system of small aspiculous keratose fibres, × 175 linear.

Suborder III. Solid, entirely spiculate, kerato-fibrous skeletons.

CHALINA, *Grant.*

Skeleton fibrous. Fibres keratose, solid, cylindrical, and interspiculate. Rete symmetrical; primary lines radiating from the basal or axial parts of the sponge to the distal portions. Secondary lines of fibre at about right angles to the primary ones.

Type, *Chalina oculata,* Bowerbank.

The type of this genus, *Halichondria oculata,* Johnston, differs so materially in the structure of its skeleton from that of the type of *Halichondria, H. panicea,* Johnston, that it becomes necessary that a distinct genus should be established to receive it and other closely allied British species. The skeleton consists of a solid, cylindrical, keratose fibre, enclosing a single or compound series of spicula, imbedded at or near its centre, and disposed in lines parallel to its axis; thus forming a structural group intermediate between that of *Halichondria panicea* and *Spongia officinalis.*

In the sponges of this genus the spicula are decidedly subservient to the fibre, which is always cylindrical, and generally very uniform in its diameter throughout the whole of a section made at right angles to its surface; while in the nearly allied genus, *Isodictya,* the reverse is the case, the spicula being the essential basis of the skeleton, while the surrounding keratode, although often abundant, is still only the subservient cementing medium of the skeleton, and never assumes the decidedly cylindrical form of that of the fibre of *Chalina.*

In the 'Edinburgh Encyclopædia,' vol. xviii, p. 844, Dr. Grant proposed the name *Halina* to represent those species which were designated *Halichondria* by Dr. Fleming, and subsequently by Dr. Johnston, in his 'History of

British Sponges,' but as I have already proposed to restrict the term *Halichondria* to those species which agree in structure with the original type of that genus, *H. panicea*, Johnston, it becomes necessary to select other names to represent the sponges which differ essentially in their structure from that type, and I therefore propose to adopt Dr. Grant's genus *Chalina*, designated in his 'Tabular View of the Animal Kingdom,' published in 1861, to represent that portion of them which agree in structure with the well-known species described in the 'History of the British Sponges' as *Halichondria oculata*. Fig. 262, Plate XIII, represents the fibres of *Chalina oculata*, Bowerbank (*Halichondria*, Johnston), illustrating the structure of spiculated keratose fibre, and Fig. 263 exhibits the mode of growth of the fibre in *Chalina Montagui*, Bowerbank, (*a*) the apical spiculum of the growing fibre.

Suborder IV. Simple fistulo-kerato-fibrous skeletons.

The type of this suborder is Lamarck's *Spongia fistulosa*. The anatomical structure and the general habits of the sponges of this description are so widely different from the true Spongias, that I was induced to establish them as a separate genus, and I accordingly designated and described them as such in the 'Annals and Magazine of Natural History' for December, 1845, vol. xvi, p. 400, plate xiii, fig. 7. It is unnecessary to enter here into a detailed account of these tissues, as I have described the peculiarities of the structure of the simple fistulo-keratose fibrous skeletons at length in describing the nature and structure of the fibrous tissues of Spongiadæ. Fig. 266, Plate XIII, represents the simple keratose fibre from *Spongia fistularis*, Lamarck, $\times$ 108 linear.

The genus may be characterised as follows:

VERONGIA, *Bowerbank.*

SPONGIA, *Lamarck.*

Skeleton kerato-fibrous. Fibres cylindrical, continuously fistulose, aspiculous. Rete unsymmetrical.

Type, *Verongia fistulosa*, Bowerbank.

Suborder V. Compound fistulo-fibrous skeletons.

This suborder is founded on the peculiarities in the structure of the skeleton fibre of a sponge described by me in the 'Annals and Magazine of Natural History' for December, 1845, vol. xvi, p. 405, plate xiii, figs. 1, 2, and also in the account I have given of the fibrous structure of the Spongiadæ in this volume. Fig. 268, Plate XIV, represents one of the fibres of the skeleton, × 100 linear, with minute tubular fibres (*a*) which traverse the central cavity of the large fibres. Fig. 267, Plate XIII, represents a portion of one of the skeleton fibres, exhibiting the secondary canals radiating from the primary ones, × 300 linear.

The genus *Auliskia* is the only one in which compound fistulo-keratose fibres have been found, and it may be thus characterised:

Auliskia, *Bowerbank*.

Skeleton kerato-fibrous. Fibres aspiculous, cylindrical, continuously fistulose, primary fistulæ having minute cæcoid canals radiating from them in every direction. Rete unsymmetrical.

Suborder VI. Regular, semi-areno-fibrous skeletons.

The sponges of this suborder have the faculty of appropriating extraneous matter, such as grains of sand or the spicula of other sponges, which become imbedded in the centre of the cylindrical fibres of their skeletons. The fibres in these cases are regular and cylindrical, and the space between their surfaces and the central line of extraneous matter is frequently one fourth or one third of their own diameter. The central axis of extraneous matters

usually consists of a series of single grains, but occasionally we find two or three compressed together. In some genera belonging to this suborder the arenation of the fibres is confined to the primary or radial ones, and the secondary system of fibres are destitute of extraneous matters. In other genera they occur occasionally in the secondary system as well as in the primary one. In *Stematumenia* the primary fibres are frequently somewhat compressed, and are abundantly arenated. The smaller or secondary series of fibres are usually cylindrical, and most frequently without either grains of sand or spicula. Several of the common Bahama sponges of commerce belong to this suborder, but the best type is the genus *Stematumenia*, described by me in the 'Annals and Magazine of Natural History' for December, 1845, vol. xvi, p. 406, plate xiv, figs. 1, 2. The genus may be characterised as follows:

STEMATUMENIA, *Bowerbank.*

Skeleton. Primary fibres solid, more or less compressed, containing a central axial line of spicula and grains of extraneous matters. Interstitial structures abundantly fibro-membranous.

Fig. 256, Plate XII, represents the fibro-membranous tissue from the dermal membrane of a species of *Stematumenia*. The fibres are disposed without order, × 183 linear; and Fig. 381, Plate XXXVII, a portion of a Stematumenia exhibiting the skeleton fibres with the axial line of sand and other extraneous matters, and the fibro-membranous tissue *in situ*, × 175 linear.

Suborder VII. Irregularly and entirely areno-fibrous skeletons.

Types, *Dysidea fragilis*, Johnston.
Dysidea Kirkii, Bowerbank.

The peculiarity of this suborder is that the fibre of the

skeleton is a full and complete but elongate aggregation of particles of sand, each separately coated by keratode, forming a series of stout anastomosing fibres, consisting of innumerable extraneous molecules encased by a thin coat of keratode.

In *Dysidea Kirkii*, an Australian species, both the primary and secondary fibres of the skeleton are comparatively large, frequently exceeding half a line in diameter. In our British species, *Dysidea fragilis*, Johnston, the primary fibres are often as abundantly arenated as those of the Australian species, while the secondary ones are only partially filled with extraneous matter, and in this condition they are frequently more or less tubular. The structure and peculiarities of the above-named two species are described in detail in vol. i, p. 63, plate vi, of the 'Transactions of the Microscopical Society of London.' Fig. 270, Plate XIV, represents a portion of one of the skeleton fibres of *Dysidea fragilis*, Johnston, exceedingly full of sand, $\times$ 108 linear. Fig. 272 exhibits the mode in which a fibre takes up and envelopes a particle of sand, $\times$ 108 linear; and Fig. 271 represents a small piece of the sponge in its natural state, $\times$ 108 linear.

ON THE DISCRIMINATION OF THE SPECIES OF THE SPONGIADÆ.

One of the reasons why so little progress has been made in our knowledge of the Spongiadæ, is that the generic and specific characters that are visible to the unassisted eye, such as form and colour, are in this class of animals remarkably uncertain and delusive, while all those that are definite and constant require not only a high degree of microscopical power to make them visible, but frequently also a peculiar mode of treatment to render them apparent even beneath the microscope. Thus it is with many of the finer forms of stellate spicula, which are very characteristic in *Tethea*, *Geodia*, *Spongilla*, and other genera. When we search for them by the dissolution of the tissues in nitric

acid, they are so minute that by far the greater part of them, even with the most careful treatment, are washed away; and when the tissues in which they are imbedded are examined in water, they are totally invisible in the sarcode in which they are immersed; and it is only when small portions of such tissues are mounted in Canada balsam that they become distinctly visible *in situ*. The correct classification, therefore, as well as the anatomy and physiology, is really a microscopical science; and it is only since we have possessed instruments of high defining and penetrating powers, that we have been properly prepared for the investigation of the structures and the correct determination of the generic and specific characters of these interesting and curiously constructed animals. A careful and patient examination of their component parts is therefore absolutely necessary for the determination of species, and the whole of the structures present should be noted, and their peculiarities accurately described.

In the first place we will consider what are the parts of the organization of the Spongiadæ that may be used for the purposes of specific distinction; and secondly, endeavour to form an estimate of their relative values.

The parts of the sponge to be thus employed are as follows:—1. The Spicula. 2. The Oscula. 3. The Pores. 4. The Dermal Membrane. 5. The Skeleton. 6. The Interstitial Membranes. 7. The Intermarginal Cavities. 8. The Interstitial Canals and Cavities. 10. Sarcode. 11. Ovaria and the Gemmules.

1. *The Spicula.*

The spicula in the descriptions of the Spongiadæ are of about the same relative value that the leaves of plants are in botanical descriptions. I have shown in the preceding portion of this work, that they are exceedingly various in form in the different species; and even when of the same shape in two different sponges, as represented in Figs. 1, 2, Plate I, their relative proportions are frequently so distinctly

different, as to render them almost as valuable as if they varied from each other in form. Wherever therefore spicula form a component part of the skeleton, they become a leading character in the discrimination of species. But it is not only those of the skeleton that are thus available, as in different sponges they vary in shape and size in each separate organ belonging to the animal; and in some cases we find as many as five or six distinct descriptions of spicula, each of which affords an invariable and excellent character. Thus, in the descriptions of sponges, it is not only the forms and relative proportions of the skeleton spicula which have to be taken into consideration, but those also of the dermal and interstitial membranes (the external and internal defensive ones), those of the sarcode, and of the ovaries and gemmules. Those of the latter three organs named frequently afford the most determinative characters. Thus in the genus *Spongilla* but one form of spiculum, the acerate, prevails in the skeletons of nearly all the known species; but the minute and beautiful spicula of the ovaria varies in form and size in each species in a perfectly unmistakeable manner, so that if the organs of reproduction be present, which is most frequently the case, the species may be readily recognised from their spicula only. But in other cases, and even in the same genus in the absence of the ovaria, the differences between two nearly allied species are equally well determined by the spicula of the dermal and interstitial membranes. Thus in our two species of British *Spongilla*, *S. fluviatilis* has no tension spicula different from those of the skeleton, while in *S. lacustris* we find the fusiformi-acerate entirely-spined spiculum, represented by Fig. 90, Plate IV, in abundance. So likewise in two species of *Tethea*, *T. cranium* from Shetland, and *T. simillima*, Bowerbank, MS., from the Antarctic regions, the only well-determined difference that exists is, that the sarcode of the former is profusely furnished with exceedingly minute sigmoid spicula, while that of the latter is entirely destitute of them. It will therefore be seen that these exceedingly minute organs frequently afford the most valuable and certain means of discriminating species. But although so minute,

we must not imagine that it is very difficult to obtain these characteristic evidences; for, as I shall show more at length hereafter, it requires but the dissolution of a small piece of the sponge in hot nitric acid to at once furnish us with a general view of the whole of the spicular contents of the sponge under examination; so that, to one who has become familiarised with the general characteristics of the forms and sizes of the different classes of spicula peculiar to each organ of the sponge, such a preliminary observation at once indicates the nature and especial seat of the principal specific characters of the subject under examination.

In some sponges the relative variation in size of the adult skeleton spicula is greater than in others; but this variation, although sometimes a substantial character, must not be always assumed to be correct, as in young sponges with simple forms of skeleton it is very difficult to discriminate between the young and only partially developed spicula and the adult ones. Thus in a young specimen of *Spongilla fluviatilis*, I found in the same field of view one spiculum perfectly well proportioned, which measured $\frac{1}{324}$th of an inch in length and $\frac{1}{10,000}$th of an inch in diameter; another $\frac{1}{241}$th of an inch in length and $\frac{1}{7500}$th of an inch in diameter; the length and diameter of an average-sized spiculum of the species in a fully developed condition being, length $\frac{1}{75}$th of an inch, and diameter $\frac{1}{2000}$th of an inch.

Abnormal or immature forms must not be mistaken for fully developed and normal ones, as we find in some of the more complicated forms of spicula that the development of form is quite as progressive as that of size; as instanced in Figs. 73, 74, 75, and 76, Plate III, which represent the progressive stages of development of the spinulo-recurvo-quaternate form of spiculum, and also in Figs. 144, 145, 146, and 147, Plate VI, representing the progressive development of the dentato-palmate inequi-anchorate spiculum.

2. *The Oscula.*

The oscula frequently afford good specific characters. Their peculiarities are, first, those of position; and secondly,

those of form. Thus it should always be noted whether they are dispersed or congregated; whether disposed on the exterior surface, or on the parietes of internal cloacæ. In form they are either simple orifices, or they assume a tubular shape to a greater or a less degree, and sometimes they are bounded by a slightly elevated marginal ring. All these characters are subject to a considerable amount of variation, which are sometimes dependent on peculiarities of locality, and at others on age or the amount of their development; but a comparison of several specimens of the same species will generally lead the observer to a correct conclusion regarding their normal characters.

In some species these organs are always more or less open; in others, especially littoral ones, they are entirely closed during exposure to the atmosphere, or while in a state of repose, during which condition they are frequently completely inconspicuous.

3. *The Pores.*

The pores afford but very few available characters. They are either dispersed or congregated; very rarely in the latter state. They are also either conspicuous or inconspicuous; that is, in the former condition their presence, and the areas within which the groups of them are situated, may be readily detected by the aid of a hand-lens, or in the latter case they are perfectly undistinguishable without high microscopic power.

4. *The Dermal Membrane.*

The dermal membrane affords many important specific characters. In the greater number of the Spongiadæ it is a simple pellucid membrane, which invests the whole of the mass of the sponge; but in other cases it is of much more complex structure, sometimes furnished abundantly with primitive fibrous tissue, or a network of spicula or kerato-fibrous tissue for its especial support; and in the areas of such network there are frequently tension spicula differing

in construction from those of the skeleton, and its interior surface is often supplied with anchorate retentive spicula of various forms. In its sarcodous lining there are occasionally an infinite number of stellate or sphero-stellate spicula to protect it from the ravages of minute enemies, and its surface is also often penetrated by large or small defensive spicula. Occasionally its external surface is profusely supplied with elongo-stellate defensive spicula. It has also frequently a thick stratum of cellular structure of various colours.

These peculiarities of structure have no generic value. They are essentially specific differences; and it is rarely the case that any two species, even in an extensive genus, are found to agree in the possession of the number, form, or mode of disposition of these peculiarities of the dermal tissues. They form therefore a constant and highly valuable series of characters, and claim the especial attention of the student in either the recognition or description of an unknown species.

5. *The Skeleton.*

Although the material, mode of structure, and arrangement of the skeleton is more especially devoted to the formation of the orders and suborders, it still presents us with a sufficient number of minor peculiarities to render it a source of valuable specific characters. Thus, as I have already shown in treating of the relative value of the spicula for the distinction of species, the difference in their size affords a good character. The closer or more diffuse mode of their arrangement modifies to a great extent the form and size of the areas in spiculo-reticulated skeletons, and their habitually greater or less number in the thread of the reticulations produces a distinctly different aspect in the skeletons of two otherwise closely allied species. The presence or absence of defensive spicula, the mode of armature, and the forms of the defensive and other auxiliary spicula also afford a very extensive and valuable series of specific characters. In the kerato- and siliceo-fibrous

sponges there are peculiarities of a similar description, such as the presence of a reticulo-fibrous sheath, as represented by Figs. 279, 280, Plate XVI, or the possession of spines or tubercles of various forms, as represented in Figs. 275, 276, Plate XV, or of extraordinary modifications for prehension, as in the cidarate siliceo-fibrous skeleton, represented also in the same Plate, fig. 278. These and other similar structural peculiarities afford a series of characters which are usually of a permanent and very striking description.

6. *The Interstitial Membranes.*

The peculiarities of the interstitial membranes consist principally in the shape and proportions of their tension spicula, or of the forms and varieties of structure, and mode of disposition of the retentive spicula. The latter class of organs especially present a very extensive series of striking characters that are essentially specific. In the genera *Halichondria*, *Isodictya*, *Hymeniacidon* and others containing numerous species, often very closely resembling each other in all the principal structural characters, they frequently, from the strongly marked peculiarities in their form and proportions, present most valuable and decisive specific characters, as in Figs. 255, 256, 257, 258, and 259, Plate XII.

In *Alcyoncellum* and other genera the interstitial membranes are strengthened and supported by layers of primitive fibrous tissue, arranged in parallel lines, and in *Stematumenia* the same fibres abound, but they are not disposed in the same symmetrical manner; and in some sponges cellular structures are present in considerable quantities. These tissues are all more or less valuable as aids in specific distinction.

7. *The Intermarginal Cavities.*

The intermarginal cavities in the greater portion of the Spongiadæ are so indefinite in their form as to render but

little service in the distinction of species; but in *Geodia*, *Pachymatisma*, and a few other genera their structure is very much more regular, and their form, proportions, and mode of disposition afford good characters. But although of no extensive essential value themselves, their subsidiary ternate spicula present a great number of strongly marked specific distinctions, arising not only from their varieties of form and proportion, but also from their relative positions in the dermal crusts of those genera where they most abound; and their modes of disposition and connection with each other are also very characteristic.

8. *The Interstitial Canals and Cavities.*

These organs themselves present very few characters that are of much service in specific descriptions, but their subsidiary spicula are often very suggestive of the nature and character of the species. Of this description are the recurvo-ternate spicula in the interstitial cavities immediately beneath the dermal crust of some species of *Geodia*, and just without the dermal membrane of *Tethea cranium*; the remarkable groups of recurvo-quaternate spicula, represented by Fig. 292, Plate XVIII; the trenchant bihamate spicula of *Hymedesmia Johnsoni*, Fig. 112, Plate V, and Fig. 293, Plate XVIII; and many other instances of offensive or defensive spicula, either disposed in groups or singly in these canals or cavities.

9. *The Cloacal Cavities.*

The cloacal cavities are especially valuable and characteristic in the calcareous sponges. Their position, number, extent, and form; the number and position of their excurrent orifices; the mode in which those orifices are armed and the nature of that armature, or the entire absence of such defences; the internal defensive spicula, their varieties of form, and mode of arrangement,—all

these characters are highly effective and valuable as specific descriptions. In other genera of sponges the cloacæ afford striking and very effective distinction, especially in *Alcyoncellum*, *Polymastia*, *Halyphysema*, and *Hyalonema*. Among the Keratosa it also prevails to a considerable extent, but in the latter order it does not afford us the same wide range of striking characters that exist so abundantly in the cloacæ of the order Calcarea.

10. *The Sarcode.*

The universal presence and similarity in structure of the sarcode of the Spongiadæ renders the range of its use as a specific character very limited; but the spicula imbedded in its substance so abundantly in many species are so various in form, and so strikingly distinct from each other, as to afford a most valuable series of discriminative characters.

The greater portion of these spicula are more or less stellate in form. They vary in shape to a considerable extent in each group, in consequence of incomplete or complete development, and the number of the radii in the stellate forms is in many cases very uncertain; but although this amount of variation exists in each of the separate forms, there is always a limit to these differences, and a normal character present which renders it by no means difficult to decide to which class they belong. Independent of the peculiar characters of their own form and modes of radiation, their radii are frequently peculiarly and abundantly spinous, and these secondary organs are equally as constant and determinative in character as the primary radii. The latter of these characters are frequently very minute, and require the application of a high microscopic power to render them available; but they are in many cases so decisively valuable, that they should never be neglected when present. In truth, the spination of these and all other forms of spicula are of considerable value as specific characters, and their shape and direction are often indicative

of the character and purpose of the spiculum on which they are based.

The range of the stellate spicula are very considerable. They are found abundantly and constantly in *Geodia*, *Pachymatisma*, *Tethea*, *Dactylocalyx*, and *Alcyoncellum*, and in some species of *Spongilla*, *Dictyocylindrus*, and other genera.

11. *The Ovaria and Gemmules.*

Where the ovaria exist they afford excellent descriptive characters. Their construction is the same throughout the whole of the known species of *Geodia* and *Pachymatisma*. The varieties in their form, although not always easy of description, are yet readily distinguishable by a practised eye; and the difference in the degree of stoutness of the radiating spicula of which they are constructed, and the consequent fineness or coarseness of the reticulations on their surface, very often affords good discriminative characters.

In *Spongilla*, the varieties in their shape, and the strikingly distinct forms of their component spicula, render them exceedingly efficient for specific descriptions; and without them it would, in several instances among the exotic species, be very difficult to find descriptive characters to separate one species from another.

Excepting in *Diplodemia*, where the structural peculiarities of the ovarium are widely different from the preceding instances, we know very little more of these organs; but there is good reason to believe, from certain forms of spicula detected in the deep-sea soundings, the sources of which are at present unknown, that other marine sponges possess ovaria with which we are at present unacquainted.

The gemmules afford very efficient specific characters in some species of *Tethea;* but in the greater number of Halichondroid genera, although frequently present in abundance, they agree so closely in structure with each other as to render them of very little use as specific characters.

We thus find that we possess eleven distinct varieties of

organic specific characters, many of which are exceedingly prolific in materials for descriptive purposes. A long familiarity with them has assured me of their value, and of their constancy in each species. However protean the form and colour may be, the organic structures can always be recognised with certainty, provided the specimen under examination has been dried in the condition in which it has been taken from the sea. To the organic characters may be added the less definite and valuable ones of form and mode of growth, which, although less to be depended on than the organic ones, are frequently of service in conjunction with them, as leading and suggestive in the first stage of investigation.

A dependence on the specific characters to be derived from form alone inevitably leads to erroneous conclusions. Thus from trusting too implicitly to it in the descriptions of his species, Dr. Johnston, in his 'History of British Sponges,' has made two species out of one in the case of *Dysidea fragilis*, the thin coating form of this sponge being also described as *Halichondria areolata*. *Halichondria incrustans* has also been described a second time as *Hal. saburrata*. An elongated form of *Halichondria ficus* has also been again described as *Hal. virgultosa*. The type-specimen of *Halichondria sevosa*, Johnston, in the British Museum proves to be merely a thin coating variety of *Halichondria panicea*; and the type-specimen of Montagu's *Spongia digitata* in the possession of Professor Grant, *Halichondria cervicornis*, Johnston, on being microscopically examined, proved not to be a sponge but an alga. Numerous other instances of error arising from a dependence on form alone as a specific character might be cited, but those I have given above are sufficient to prove the ineligibility of so mutable a character unaccompanied by organic structure.

Nearly the whole of this extensive series of specific characters have hitherto not been applied in the descriptions of the Spongiadæ, excepting in my own manuscripts. This omission has occurred, not from any doubt of their value, but simply because they were unknown to naturalists. It

now remains to be proved how they may be rendered available in future descriptions of those animals. I cannot, perhaps, better attain this end than by detailing the order and mode of employing them in the description of species contained in my own Manuscript 'History of the British Sponges.' The following is the order in which these characters have been taken for examination and description:—

1. Form. 2. Mode of Growth. 3. Surface. 4. Oscula. 5. Pores. 6. Dermis, and Dermal Membrane and its Spicula. 7. Skeleton and its Spicula. 8. Connecting Spicula. 9. Defensive Spicula,—external, internal. 10. Spicula of the Membranes,—tension spicula, retentive spicula. 11. Sarcode and its Spicula. 12. Ovaria and Gemmules and their Spicula.

Colour.

Habitat.

Condition when examined.

This order of description, or any other that the student may prefer, should always be adhered to, and no part of the specimen under examination that is present, and which affords specific characters, should be omitted in the description; so that, when no mention is made of particular organs or classes of spicula, it may be presumed that they are not present in the sponge in course of description. A certain portion of these characters are always available. Thus the skeleton, incurrent canals or cells, the sarcodous system, the dermal and interstitial membranes, the pores, and the oscula are always present, while the excurrent canals or the cloaca are occasionally absent. The intermarginal cavities, if present, are not always distinguishable, and the external and internal defensive organs are, either one or both of them, frequently absent.

Specific characters should always be of a positive nature, such as the presence and form of particular spicula or other organs. It is a great mistake, in writing specific descriptions, to make the differences between species to consist of one or two striking essential characters only. Such a practice may answer tolerably well when there are but two or

three species of a genus known; but it frequently occurs when new species are found, that they also have the most striking essential characters of the previously known ones equally strongly developed. Much confusion is thus likely to occur from this paucity of description; whereas, if the whole of the essential characters of each species be carefully investigated and accurately recorded when it is first characterised, that description will most probably suffice permanently to distinguish it as a species, however numerous the subsequently discovered members of the genus may be.

Differential characters should never be intermingled with essential ones in characterising the species. They should be reserved for the amplified history; and here they are of much value, as they lead to the relative consideration of two or more nearly allied species, and frequently assist the student in their discrimination when the essential characters are minute or somewhat obscure.

In the description of species the adjectives long, short, stout, slender, &c., must always be understood as in comparison with the congenerous organs of the species under consideration, and not as in relation to any fixed standard of size.

In the description of a new species it should always be stated whether the characters are given from a dried specimen, or whether from one fresh from the sea, as it frequently happens that many of the *natural* characters become completely obliterated and sometimes reversed by drying; thus the surface smooth in the live state become villous when dried. Inconspicuous oscula become conspicuous when contracted and dry, and conspicuous oscula are often destroyed by desiccation, and so on with other characters. It is therefore absolutely necessary that the condition of the specimen should be stated along with its description.

On the Preservation and Examination of the Spongiadæ.

The greater portion of specimens in natural history may be readily examined and their species determined in the field; but this is rarely the case with the Spongiadæ. It becomes necessary therefore to preserve them in such a manner as to effectually retain their natural characters for examination at some future period. Small specimens may be preserved in spirit of wine, but this destroys their colour. If they are not likely to be permanently lodged in the cabinet immediately, it is better that they should be laid on blotting paper, or a soft cloth, to absorb as much as possible of the water from within them and then dry them rapidly before a fire, or in a slack oven, without any previous washing in fresh water. By this mode they retain a sufficient amount of moisture and flexibility to allow of their being handled and operated on for examination with impunity; but the amount of salt thus left within them will in time cause considerable mischief to the specimen. After such specimens have been once thoroughly dried and their examination has been completed, they may be plunged into cold water for a few minutes, and the water then ejected by a rapid centrifugal motion of the arm, and this operation repeated two or three times; the specimen should be again rapidly dried, and it will then keep well in the cabinet and preserve all its characteristic features. It is a bad habit to soak marine specimens for a considerable time in fresh water to extract the salt, as by this mode of proceeding the minute and delicate characters of the object are to a great extent destroyed.

The most advisable mode of proceeding in the examination of an unknown species, is first to note the general peculiarities of form and surface as presented to the unassisted eye.

After the noting of the external character, the next step should be to cut a slice out of the sponge, to about half an inch or more in depth at right angles to the surface, taking

special care that a due proportion of the dermal membrane is included; this should be placed in a long narrow test-tube, in about an inch deep of nitric acid, in which it should be gently and cautiously boiled over a very small flame until the sponge is entirely dissolved, and then set by until the acid is quite cold and the spicula have subsided to the bottom of the test-tube, so that the greater portion of the acid may be decanted off and its place be supplied with distilled water; and this latter operation should be repeated three or four times with much care. The spicula thus prepared should be placed in a watch-glass with a little distilled water, and the whole stirred up so that an average sample can be obtained for microscopical examination. By this mode of procedure a general view of the whole of the spicula belonging to the species will be obtained, which will serve as a guide to the subsequent modes of examination.

The boiling in nitric acid should not be continued beyond the time of the piece of sponge falling completely separated to the bottom. If stopped at this period by the addition of a little distilled water, it frequently occurs that undissolved gemmules and portions of the membranes are found that are very suggestive for the further examination of the specimen.

The next step should be to take a thin slice from the surface of the sponge, and place it in a cell in a little distilled water, for the purpose of the examination of the structural peculiarities of the dermal membrane. Then take a thin slice from the body of the sponge at right angles to its surface, and mount it in a similar manner for the purpose of ascertaining the nature and peculiarities of its skeleton and other internal organs. These two sections should be carefully examined with the microscope, and if they be not sufficiently characteristic fresh ones should be mounted. If the specimens thus treated be taken from sponges properly preserved, their tissues will expand and assume very much the appearance of those of the living sponge, and they will as nearly as possible exhibit the natural positions and proportions of the internal organs.

The general characters of these sections should be observed

with a half-inch or two-thirds combination, and again with not less than a quarter-inch object-glass, and the characters of the various tissues in their natural condition be immediately noted. But the whole of their minute organs will not be visible by this mode of examination, and it is therefore necessary to mount the same or similar sections in Canada balsam, by which means the spicula of the sarcode and other minute organs will become completely visible *in situ*, and the specimens thus mounted will serve as permanent records for the cabinet.

TERMINOLOGY,

AND DESCRIPTIONS OF THE ILLUSTRATIVE FIGURES.

Professor Ehrenberg in the course of his laborious and valuable researches into the nature of the various minute organized bodies contained in the earths of recent and ancient geological deposits, has described a large number of sponge spicula, which he has named and arranged in genera and species in accordance with their forms; but as in many species of existing sponges we find three or four of his genera and species of spicula, and in other cases we find one of his species common to a dozen or more distinct genera and species of recent sponges, it becomes impossible systematically to apply the names he has given to these organs to the descriptions of the living species of Spongiadæ with any degree of propriety or certainty. I have therefore been compelled, in constructing a terminology for the description of the Spongiadæ, to consider the names applied to those organs by my learned and highly esteemed friend, Professor Ehrenberg, as provisional terms rather than as permanent denominations, and to designate the numerous and varied forms of these organs in such a manner as to render their names as closely descriptive of their forms as possible, after the manner in which the nomenclature of botanical organs has been treated by the best writers on that science.

The quantity of new names, and of figures illustrative of them, is necessarily large, and to facilitate the references from the one to the other I have numbered the figures as a continuous series, and not with reference to each separate plate; and the descriptions of the illustrations are numbered to correspond with the figures appended to them, so as to render the references mutual; and the same system of reference is applied throughout the work, each number leading the student to both figure and description.

SPICULA OF THE SKELETON.

FIG.

1. ACERATE.—Of the same diameter for the greater part of the length of the shaft, but decreasing equally near each termination, and ending acutely at both. × 160 linear.

The proportions of length and diameter vary to a considerable extent in this form. In *Halichondria panicea*, Johnston, it is of about the medium proportions.

2. In *Spongilla fluaviatilis* it is much shorter and stouter. × 160 linear.

3. FUSIFORMI-ACERATE.—Having the greatest diameter at the middle of the shaft, and decreasing gradually to each acute termination. *Halichondria coccinea*, Bowerbank. × 160 linear.

4. INFLATO-FUSIFORMI-ACERATE.—Fusiformi-acerate, with a globular inflation at the middle of the shaft. This form of spiculum is abundant in the skeleton of *Isodictya anomala*, Bowerbank. It is sometimes extremely fusiform in shape. × 160 linear.

5 INEQUI-ACERATE VERMICULOID.—From *Hymeraphia vermiculata*, Bowerbank, Shetland. × 175 linear.

6. ACUATE.—Of the same diameter from the hemispherically-terminated base to near the acutely-terminated apex. *Halichondria Alderi*, Bowerbank. × 160 linear.

7. ACUATE.—From *Hymeniacidon caruncula*, Bowerbank. × 160 linear.

8. FUSIFORMI-ACUATE.—Having the largest diameter near the middle of the shaft, and decreasing thence gradually towards the hemispherical base and the acute apex. *Halichondria crustula*, Bowerbank. × 160 linear.

FIG.

9. ATTENUATO-ACUATE.—Decreasing gradually in diameter from the hemispherical base to the acutely terminated apex. *Halichondria infundibuliformis*, Johnston. × 160 linear.

10. FLECTO-ATTENUATO-ACUATE.—Attenuato-acute bent suddenly near the base of the spiculum. *Isodictya infundibuliformis*, Bowerbank. × 160 linear. In other species of sponges, and in other forms of spicula, the bending near the base is not so abrupt but it is still characteristic and constant in the species, as for example in the following form:

11. FLECTO-ACUATE.—*Halichondria variantia*, Bowerbank. × 160 linear.

12. CYLINDRICAL.—Having the shaft of the same diameter throughout its length, and terminating at each end hemispherically, as in *Pachymatisma Johnstonia*, Bowerbank. × 90 linear.

13. FARCIMULO-CYLINDRICAL.—From *Spongilla coralloides*, Bowerbank. In the Museum of the Royal College of Surgeons. × 108 linear.

14. NODULATED - CYLINDRICAL VERMICULOID.—From soundings in the Atlantic 2070 fathoms. × 175 linear.

15. FUSIFORMI-CYLINDRICAL.—Having both terminations hemispherical, and the shaft gradually increasing in diameter to its middle. *Pachymatisma Johnstonia*, Bowerbank. × 90 linear.

—. DOLIOLATE-CYLINDRICAL.—See No. 94, and same number, Plate IV.

16. FLEXUOUS-CYLINDRICAL.—Having the shaft of the spiculum curved repeatedly. From *Phakellia ventilabrum*, Bowerbank. × 160 linear.

17. ATTENUATO-CYLINDRICAL.—Terminating hemispherically at both ends, but the shaft slightly decreasing from the base to the apex. *Pachymatisma Johnstonia*, Bowerbank. × 90 linear.

FIG.

18. FUSIFORMI-ATTENUATO-CYLINDRICAL.—Both terminations being hemispherical, the fusiform shaft has a much smaller diameter towards its apex than it has at its base. From *Tethea robusta*, Bowerbank, MS. A new species from Australia, in the British Museum. × 90 linear.

19. BICLAVATED CYLINDRICAL.—The shaft equally cylindrical, with gradually inflated terminations. The inflations are almost as great as that of a spinulate spiculum, but without sphericity. From a new and undescribed species from Australia, Bowerbank collection. × 260 linear.

20. INEQUI-BICLAVATED CYLINDRICAL.—The shaft attenuated from the base to the apex, with clavated terminations of unequal diameters. From *Pachymatisma Johnstonia*, Bowerbank. × 90 linear.

21. ANGULATED INEQUI-BICLAVATED CYLINDRICAL.—This singular angulated form does not appear to be purely accidental, as I have found other instances of similar angulation at the middle of the shaft in other sponges, and the angle in each instance has been as nearly as possible at the same spot in the shaft. *Pachymatisma Johnstonia*, Bowerbank. × 90 linear.

22. SPINULATE.—Shaped like a pin, having the same diameter from the spherical base to very near the acutely terminated apex. *Hymeniacidon carnosa*, Bowerbank. × 260 linear.

23. FUSIFORMI-SPINULATE.—The base being spherical, the shaft more or less fusiform and terminated acutely. *Hymeniacidon suberea*, Bowerbank. × 260 linear.

24. DEPRESSO-SPINULATE.—Having the basal inflation considerably depressed, the shaft having the same diameter to very near the apex. From an undescribed species of sponge from Ash Island. × 160 linear.

FIG.

25. OVO-SPINULATE.—The basal inflation being oviform, the smallest portion being at the extreme basal point. From *Tethea spinularia*, Bowerbank. × 308 linear.

26. ENORMI-SPINULATE.—Having the spherical inflation slightly within the basal portion of the shaft of the spiculum. *Hymeniacidon celata*, Bowerbank. × 260 linear.

—. BISPINULATE.—See No. 228, and Plate X, same number.

—. TRISPINULATE.—See No. 229, and Plate X, same number.

27. ENSIFORM.—Expanding towards the apex, but terminating acutely; so that the outline has more or less the form of the blade of a sword. Sponge unknown. × 130 linear.

28. ENTIRELY SPINED.—When the spines are equally dispersed over the spiculum from the base to the apex. *Halichondria incrustans*, Johnston. × 260 linear, Pages 38, 40.

29. BASALLY SPINED.—When the spines do not occupy more than about one-third of the length at the basal portion of the spiculum. *Halichondria Ingalli*, Bowerbank. × 260 linear.

30. MEDIALLY SPINED.—When the spines occupy only about one-third of the length at the middle of the spiculum. *Halichondria Ingalli*, Bowerbank. × 260 linear, Page 38.

31. APICALLY SPINED.—When the spines occur only at and near the apex of the spiculum: from an undescribed sponge, locality unknown. × 160 linear.

32. TERMINALLY SPINED.—When the spines occur near both the base and apex of the shaft of the spiculum but not at the middle: from an undescribed species of sponge, locality unknown. × 160 linear, Page 38.

Fig.

33. Sub-attenuato entirely spined cylindrical.—From *Hymeniacidon Cliftoni*, Bowerbank, MS. Freemantle, Western Australia. × 400 linear.

34. Clavato-attenuato-cylindrical, apex stellately spinous.—From *Hymeraphia stellifera*, Bowerbank. × 260 linear. All the spicula of this sponge appear to combine the offices of skeleton and defensive spicula, Page 189.

35. Elongo-attenuato-stellate.—Having the radii springing from an elongated instead of a central base. This form of spiculum occurs abundantly in *Tethea muricata*, Bowerbank, MS. From Vigten Island, Norway. It is both externally and internally defensive. × 308 linear, Page 22.

36. Equiangular triradiate.—Having the three attenuating rays in the same plane, and the intervening angles equal, or very nearly so. *Grantia compressa*, Fleming. × 160 linear, Page 163.

37. Rectangular triradiate.—Having the three attenuating rays in the same plane, two of them forming a straight line, and one being projected from the middle of the line, forming right angles to it. Abundant in the base of the ciliary fringe of the mouth of the cloaca of *Grantia tessellata*, Bowerbank. × 260 linear.

38. Elongo-equiangulated triradiate.—From *Grantia striatula*, Bowerbank, MS. × 108 linear. Madeira. Exhibiting an extreme development of the elongated ray. This form occurs also in the intermarginal cavities in *Grantia compressa*.

39. Exflected elongo-equiangulated triradiate.—From *Grantia striatula*, Bowerbank, MS. × 108 linear. Madeira. Abundant on the surface of the pedicel of the sponge; and also *Grantia compressa*, see Fig. 312.

40. Equiangular triradiate.—A very stout variety of form, from an undescribed African calcareous sponge. × 90 linear.

Fig.

41. Trifurcated patento-biternate.—Consisting of a short stout shaft, each end being furnished with three short equiangular radii passing off at right angles to the shaft, and each having its termination trifurcated. × 90 linear. This singular form occurs in the tortuous excavations of probably a small annelid in a soft limestone, the sponge lining the cavities in a manner similar to *Hymeniacidon celata*, Bowerbank. The skeleton consists entirely of this singularly complicated form of spiculum.

42. A view of one end of the spiculum represented by Fig. 41. × 90 linear.

43. Biangulated quadriradiate.—Having two radii projected from a common basal point, in one plane forming an angle of about 90°, and the other two projected in a similar manner in an opposite direction in a second plane at right angles to the first one. × 90 linear.

This singular form is associated with the spiculated triradiate one in the skeleton of *Hymeniacidon Bucklandi*, Bowerbank.

44. Equiangular spiculated-triradiate.—Having the three rays in the same plane with the intervening angles equal, and a fourth ray projected from the basal junction of the radii at right angles to their plane. *Hymeniacidon Bucklandi*, Bowerbank. × 90 linear.

This form is very common in the calcareous sponges, where it appears as a defensive organ.

CONNECTING SPICULA.

45. Expando-ternate.—Having the terminal radii projected forward at angles varying from 45 to 60 or 70 degrees to the long axis of the shaft. From *Pachymatisma Johnstonia*, Bowerbank. × 90 linear.

Fig.

—. Expando-ternate.—See No. 128, and Plate V, same number.

—. Incurvo-porrecto-ternate.—See No. 129, and Plate V, same number.

—. Bifurcated expando-ternate.—See No. 130, and Plate V, same number.

46. Cylindro expando-ternate.—From *Pachymatisma Johnstonia*, Bowerbank. × 90 linear. Probably an incomplete development of the form represented by Fig. 45, Page 18.

47. Patento-ternate.—Having the terminating radii disposed at, or nearly at right angles to the shaft of the spiculum, the curves of the radii being usually more or less inclined backwards towards the base of the shaft. From *Geodia McAndrewii*, Bowerbank, MS. × 90 linear. Vigten Island, coast of Norway.

48. Geniculated expando-ternate.—From *Tethea Collingsii*, Bowerbank. × 108 linear. The shaft acts as a subsidiary skeleton spiculum, and the ternate apex as a defensive one.

49. Abbreviato-patento-ternate.—From a sponge allied to *Pachymatisma* in the Museum of the Royal College of Surgeons. × 108 linear. A completely developed spiculum.

50. Furcated attenuato-patento-ternate.—The radii of the ternate apex having bifurcated terminations in the same plane as the primary radii. From *Pachymatisma Listeri*, Bowerbank, MS. × 90 linear.

51. The same spiculum represented by Fig. 50. The former being erect, and the latter having the plane of the radii presented to the eye. × 90 linear.

52. Irregularly furcated patento-ternate.—From the dermis of *Dactylocalyx Prattii*, Bowerbank, MS. × 90 linear.

Fig.

53. Spiculated dichotomo-patento-ternate.—A still more complicated form than that of the Furcated patento-ternate one. The radii of the bifurcations each terminating again dichotomously; but the secondary bifurcations are not all of them in the same plane as the primary ones, a portion of them being at right angles to it, and the shaft is also carried through the common central base of the whole, giving it a spiculated form as represented in the figure. × 260 linear. Sponge unknown. Similar spicula occur abundantly in the dermis of *Dactylocalyx Bowerbankii*, Johnson, in the British Museum. × 260 linear, Page 18.

54. Recurvo-ternate.—The terminating radii, recurved from about 100 to 140 degrees from the apical line of the axis of the shaft. The curves of the radii are always more or less inclined towards the base of the shaft of the spiculum. From *Geodia Barretti*, Bowerbank, MS. × 90 linear. Page 123.

55. Spiculated recurvo-ternate.—Having three equidistant recurved radii, and the central terminal one porrect in the line of the axis of the shaft of the spiculum. From *Geodia Barretti*, Bowerbank, MS. × 90 linear. Page 22.

56. The central porrect terminal ray is often more or less deflected from the axial line of the shaft, as in Fig. 56; and occasionally, in the simple recurvo-ternate form, one of the three rays will be bent upward, even to a greater extent than is represented in Fig. 57; but these it must be recollected, are but accidental variations in form.

57. The shafts of the recurvo-ternate forms of spicula are much less in diameter than those of the patento or expando-ternate ones from the same sponge, and they are frequently very long and exceedingly attenuated.

FIG.

58. SPICULATED PORRECTO-TERNATE.—Having three equidistant porrect terminal rays, and a fourth or central one in a line with the axis of the shaft. From *Geodia Barretti*, Bowerbank, MS. × 90 linear.

PREHENSILE SPICULA.

59. APICALLY SPINED RECURVO-QUATERNATE. — From *Euplectella cucumer*, Owen. × 90 linear. Projected from the basal portion of the sponge as a means of attachment to other bodies. The recurvo-quaternate end (*a*) being the apex of the spiculum. Page 20.

DEFENSIVE SPICULA.

60. MULTIDENTATE BIROTULATE.—*Hyalonema mirabilis*, Gray. × 83 linear. This form is more especially a retentive spiculum; an auxiliary to the offensive and defensive spiculated cruciform spicula with which it is associated in the interstitial cavities of the sponge. Fig. 294.

From the basal portion of a specimen in the British Museum. Pages 37 and 127.

61. ELONGO-RECURVATE DENTATO-BIROTULATE.—From the same sponge as Fig. 60. × 308 linear.

62. RECURVO-ACUTELY DENTATE-BIROTULATE. — From soundings in the Indian Ocean, 2200 fathoms; probably from an unknown species of *Hyalonema*. × 308 linear.

63. ELONGO-RECURVATE DENTATO-BIROTULATE. — From soundings in the Indian Ocean, 2200 fathoms; from most probably an unknown species of *Hyalonema*. × 308 linear.

FIG.

64. RECURVO-DENTATO-BIROTULATE.—From soundings in the Indian Ocean, 2200 fathoms. Most probably from another unknown species of *Hyalonema*. × 308 linear.

65. INFLATO-FUSIFORMI-ACERATE ASCENDINGLY HEMI-SPINOUS. × 108 linear.—*Hyalonema mirabilis*, Gray, British Museum. Projected in abundance from the dermal surface of the sponge; the smooth basal half being immersed in the tissues beneath the dermal membrane and the spinous distal portion being projected beyond it. Purely external defensive.

66. ATTENUATO-ACUATE, ENTIRELY SPINED.—From *Dictyocylindrus ventilabrum*, Bowerbank. × 260 linear. Internal defensive. Page 29.

67. ACUATE, ENTIRELY AND VERTICILLATELY SPINED.—From an undescribed sponge, × 400 linear. Internally defensive. I have found it in two distinct species of sponge from the West Indies. In one it is irregularly dispersed, and in the other it is collected into radiating groups. See Figs. 289, 290, Page 30.

68. CYLINDRICAL: ENTIRELY AND VERTICILLATELY SPINED. × 400 linear.—I am not acquainted with the sponge whence this beautiful spiculum came. I found it in the refuse matter from the base of a specimen of *Oculina rosea*, from the South Seas. The shaft of the spiculum, from end to end, has equidistant rings of single series of acute conical spines, and the base and apex of the spiculum are each equally crowded with spines. I have arranged it as a defensive spiculum, from its near approximation to the characters of the spiculum last described; but it is subject to the doubt whether it may not ultimately prove to have belonged to the skeleton. Page 30.

FIG.

—. ATTENUATO-CYLINDRICAL VERTICILLATELY SPINED.—See 210, 238, and 239. And Plate X, same numbers.

69. VERTICILLATELY SPINED CYLINDRICAL. × 660 linear. —From an undescribed sponge from Freemantle, Western Australia. Very abundant on the dermal and interstitial membranes. Internally and externally defensive.

70. SUB-ATTENUATO-ENTIRELY SPINED CYLINDRICAL. × 400 linear.—From *Hymeniacidon Cliftoni*, Bowerbank, MS., Freemantle, Western Australia. Internal defensive.

71. MULTIANGULATED CYLINDRICAL. × 400 linear.—From a sponge in the British Museum; accidentally entangled in its tissues. The same form occurs in the interstitial membranes of *Geodia carinata*, Bowerbank, MS., figured in Plate xxxvi, Fig. 42, 'Phil. Trans.,' 1858, page 314.

72. SPINULO-MULTIANGULATED CYLINDRICAL. × 660.—Found among the extraneous spicula of the same sponge that produced the one represented by Fig. 71. It is in the Johnstonian collection in the British Museum. It is designated *Halichondria sanguinæ*, and its register is 47. 9. 7.19.

73. SPINULO-RECURVO-QUATERNATE. × 130 linear.—Representing its first stage of development. Page 34.

74. The same form of spiculum as represented by Fig. 73, in its second stage of development. × 130 linear.

75. The same form of spiculum as represented by Fig. 73, in its third stage of development. × 130 linear.

76. The same form of spiculum as represented by Fig. 73, in a completely developed state. × 130 linear. From an undescribed species of sponge. Locality unknown. Internally defensive. See Plate XVIII, Fig. 292. The gradual development of this form of spiculum is very instructive. Pages 32, 33, and 34.

Fig.

77. Fusiformi-porrecto-ternate, a very early stage of development, from *Tethea cranium*, Johnston. × 660 linear.
78. A further stage of development of a fusiformi-porrecto-ternate spiculum from *Tethea cranium*, Johnston. × 260 linear.
79. An adult fusiformi-porrecto-ternate spiculum from *Tethea cranium*, Johnston. × 160 linear.
80. A fusiformi-porrecto-ternate spiculum from *Tethea cranium*, Johnston, charred to exhibit the cavities of the shaft and radii. × 260 linear.

These spicula form the greatest portion of the fasciculi of defensive spicula with which the external surface of *Tethea cranium* is armed. They are very long and slender, frequently exceeding a quarter of a inch in length, with a diameter of $\frac{1}{1415}$th of an inch at the thickest portion of the shaft. The ternate radii are projected from the apex of the shaft at about an angle of 20° from its axis, and are about $\frac{1}{150}$th of an inch in length. See Fig. 362, *a*, Plate XXXI.

81. Fusiformi-recurvo-ternate spiculum, in an early stage of development, from *Tethea cranium*, Johnston. ×260 linear. Page 32.
82. Fusiformi-recurvo-ternate, an adult spiculum from the same sponge as the spiculum represented by Fig. 81. × 260 linear. Page 32.

This form of defensive spiculum occasionally accompanies the porrecto-ternate ones of the defensive fasciculi of *Tethea cranium*. The length and proportions of the shaft of the former are very much the same as those of the latter. The recurvate apex of the spiculum undergoes a progressive development, which does not appear to commence until after a great extent of the length of the slender flexible shaft has been produced, when an enlargement of the apex of the shaft takes place, and the rudiments of the stout recurvate radii appear as represented by Fig. 81, and between this and the fully-developed form, fig. 82, all

FIG.

the intermediate gradations of development may be observed among the spicula of young specimens of the sponge. The two figures are drawn by the same power, 260 linear, and the difference in size between the young and the fully-developed spiculum is very remarkable.

This form is both defensive and retentive, internally and externally. See Fig. 354*e*, Plate XXVIII, and Fig. 362 *c*, Plate XXXI.

83. ATTENUATO-CLAVATE: INCIPIENTLY SPINED.—The enlargement of the base of this spiculum is not spherical as in a spinulate form, but it expands more or less gradually and is usually exaxial. They are projected in abundance into all parts of the interstitial cavities of *Hymeniacidon clavigera*, Bowerbank. × 130 linear.

84. EQUIANGULAR TRIRADIATE: VERTICILLATELY SPINED.—This beautiful spiculum was found among minute fragments of various sponges scraped from the bases of specimens of *Oculina rosea*. I have not hitherto found verticillately spined sponge spicula under any other character than that of defensive spicula, and I have therefore arranged this one as such until further information shall be obtained regarding it. × 400 linear.

85. ENSIFORM SPICULATED EQUIANGULATED TRIRADIATE.—The spicular ray is at right angles to the common plane of the basal radii, but not of the same form. It is very much longer and stouter than the basal radii, and its diameter is considerably increased in the distal third. Internal defensive. × 130 linear. From the cloaca of *Grantia ensata*, Bowerbank. Page 29.

86. A variety of the same form of spiculum as that represented by Fig. 85. From the cloaca of *Grantia tessellata*, Bowerbank. × 130 linear. See Fig. 286, Plate XVII, *in situ*. Page 29.

FIG.

87. SPICULATED EQUIANGULATED TRIRADIATE.—When the spicular ray is of the same form and at right angles to the common plane of the basal radii, from *Leuconia nivea*, Bowerbank. × 45 linear. Page 29.

88. EQUIANGULATED TRIRADIATE: UNIRADIALLY SPINED.—I obtained a considerable number of this form of spiculum from the dissolution in nitric acid of a small fragment of a parasitical sponge, in the collection of the late Mr. Charles Stokes. I have not seen it *in situ*, but I have very little doubt from its structure that the spiculated ray is a defensive one, while the two spineless rays formed part of the skeleton. × 130 linear.

89. EQUIANGULATED SPICULATED TRIPODATE.—When the basal radii are projected backward so that their apices only are in the same plane, and the spicular ray at right angles to that plane. The short spicular ray in this case is not based on a triradiate skeleton one, but the whole speculum is essentially a defensive one only. They occur in the lining membrane of the cloaca of *Leuconia nivea*, Bowerbank, and are very minute. × 660 linear.

—. SPICULATED INEQUI-ANGULATED TRIRADIATE, WITH CYLINDRICAL ENTIRELY SPINED RADII. See No. 234, and same number, Plate X.

—. SPICULATED ATTENUATO-EQUIANGULAR: VERTICILLATELY SPINED. See No. 235, and same number, Plate X.

—. SPICULATED CYLINDRO-EQUIANGULAR TRIRADIATE: VERTICILLATELY SPINED. See No. 236, and same number, Plate X.

—. INEQUI-FURCATO-TRIRADIATE. See No. 237, and same number, Plate X.

SPICULA OF THE MEMBRANES.

TENSION SPICULA.

FIG.

90. FUSIFORMI-ACERATE: ENTIRELY SPINED. × 660 linear.—This form of spiculum occurs abundantly in the dermal and interstitial membranes of *Spongilla lacustris*, Johnston. Pages 38, 42, and 58.

91. FUSIFORMI-ACERATE: TRUNCATEDLY SPINOUS. × 660 linear.—Abundant in *Spongilla alba*, Carter, in both the dermal and interstitial membranes. Page 42.

92. MUCRONATO-CYLINDRICAL. × 400 linear.—The dermal membrane of *Halichondria incrustans*, Johnston, is abundantly furnished with large flat fasciculi of this form of spiculum. They are as long as those of the skeleton, but not above half their diameter; they are entirely destitute of spines, while the spicula of the skeleton are covered with those organs. Page 40.

—. TERMINALLY SPINED SUBFUSIFORMI-CYLINDRICAL.—This form of spiculum is abundant in the dermal membrane of *Halichondria nigricans*, Bowerbank, where it occurs in irregular fasciculi. It is as long as the spicula of the skeleton, but has not quite so great a diameter, and is distinctly different in its form.

93. TUBERCULATED FUSIFORMI-CYLINDRICAL. × 660 linear.—These minute spicula are profusely dispersed on the inner surface of the dermal and interstitial membranes of *Pachymatisma Johnstonia*, Bowerbank. They are covered very irregularly with ill-defined tubercles. They vary very considerably in form and proportions. Their average dimensions are, length $\frac{1}{857}$th inch, diameter $\frac{1}{5000}$th inch. Page 42.

FIG.

94. DOLIOLATE CYLINDRICAL. × 175 linear.—From a sponge nearly related to *Ecionemia*, Bowerbank. Locality unknown. From the similarity of the form to Fig. 93, it is probably a tension spiculum.

95. INFLATO-CYLINDRICAL. × 660 linear.—This form of spiculum is very minute. It is slightly curved, and has a single, well-defined bulbous inflation near the middle of the shaft, but in this respect, as well as in size, there is, comparatively, a considerable amount of variation. The normal condition of the inflation is equidistant from the ends of the spiculum, but in some cases it is not more than a third of the length of the spiculum from one end of it. The only sponge in which I have found this form is *Hymeniacidon ficus*, Bowerbank, where it occurs in the dermal membrane in great profusion.

96. 97. 98. TRICURVATO-ACERATE. × 260 linear.—This form of spiculum has always three curves in the course of its length, one at the middle of the shaft, and one near each termination, the terminal ones curving in the same direction, and always opposite to that of the central curve.

These spicula vary greatly in form and proportions in different sponges, and frequently even in the same species. The normal form is that of three curves of about equal value, (Fig. 96,) but sometimes, as in Fig. 97, the central curve is very much the larger of the three, while in Fig. 98 we find the extreme condition of the form, the spiculum being comparatively straight, with a very small curve in the centre of the shaft, and the terminations exhibiting only the rudiments of curves in an opposite direction to the middle one. They are usually very much more slender than the spicula of the skeleton, and are comparatively of rare occurrence in every species in which I have found them. I have never seen them *in situ* with the ter-

FIG.

minal curves elevated above the surface of the membrane, but always reposing on one side, with all parts of the shaft closely attached to its surface. The three forms figured are from the same specimen of sponge. Page 41.

99. UNICURVO-CRUCIFORM. × 130 linear.—This form occurs abundantly on the membrane lining the great cloacal cavities of *Leuconia nivea*, Bowerbank. The axial radii are disposed very nearly in the direction of the long axis of those organs, and the curves formed by the lunate radii always have their points towards the mouths of the cloaca.

100. FALCATO-ACERATE. × 130 linear.—This form is abundant in a small species of *Grantia* from Australia, which is found on several species of Fuci in the collections brought home by Dr. Harvey. The sponges do not frequently exceed the eighth of an inch in length. Page 41.

101. BICURVO-ACERATE. × 260 linear.—This form is from a small parasitical *Grantia* from Algoa Bay, in my collection. The sponge is about the size of a large pea, and is not uncommon on Zoophytes from that locality. Page 41.

102, 103, 104, 105, 106, 107, 108. FOLIATO PELTATE. These spicula have the shaft exceedingly short and conical; the basal termination being acute, and the shaft dilating rapidly to its distal end, to the extent of an angle of about 15 or 20 degrees. The apex of the spiculum expands into a large, more or less, circular disc or shield, having in the fully developed state an extremely sinuous or foliated margin; the plane of the shield or disc being at about right angles to the line of the shaft, and having the under side thickly studded with tubercles, which are separate in the young spicula, and more or less confluent in the fully developed ones. In an early stage of its development

FIG.

the peltate apex of the spiculum is irregularly circular, and entirely devoid of the complex and beautiful sinuous foliations that render the adult spicula such elegant objects. Fig. 102. × 260 linear. As the development proceeds it assumes a trilobular shape, Fig. 103, × 160 linear, and the margins are slightly indented or serrated.

In a further advanced condition, the sinuation of the margin becomes deeper and more complex, as represented in Figs. 104, × 160 linear, and 105, × 160 linear, until at last it becomes, in the fully developed peltate apex, so deeply and irregularly sinuated as to nearly obliterate all traces of its original trilobular character (Fig. 106). × 130 linear. Fig. 107, × 160 linear, represents a side view of a spiculum exhibiting the form and comparative length of the shaft. Fig. 108, × 260 linear, exhibits the furcated terminations to two out of the three radiating canals of the apex of the spiculum.

RETENTIVE SPICULA.

109. SIMPLE BIHAMATE.—Acerate spicula, having each end of the spiculum curved in the form of a hook in the same plane and towards each other. From *Halichondria variantia*, Bowerbank, × 1060 linear, Page 43.

110. REVERSED BIHAMATE SPICULA.—Having each end of the spiculum curved in the form of a hook in the same plane, but in opposite directions to each other. From *Halichondria incrustans*, Johnston. × 1060 linear.

111. CONTORT BIHAMATE SPICULA.—Having each end of the spiculum curved in the form of a hook but in planes at right angles to each other. From *Halichondria incrustans*, Johnston. × 1060 linear.

FIG.

112. TRENCHANT CONTORT BIHAMATE.—Shewing the cylindrical form of the shaft at the curves of the hooks, and the middle of the spiculum, and the trenchant edges of the remainder of its inner surface. × 400 linear. *Hymedesmia Johnsoni*, Bowerbank, MS. From Madeira, Pages 35, 127.

113. ABBREVIATED BIHAMATE.—From an unknown sponge. × 1060 linear. I have found but very few specimens of this form, and in no case *in situ;* and I am therefore in doubt whether it be an adult spiculum, or merely a variety arising from an arrest of development.

114. DEFLECTED BIHAMATE.—When the hami are both deflected in the same direction at nearly right angles to the plane of the shaft. From *Farrea occa*, Bowerbank, MS. The sponge is at the base of *Euplectella cucumer*, Owen. × 660 linear.

115. EXTER-UMBONATE BIHAMATE.—When the umbo is on the middle of the outer curve of the shaft; from an undescribed sponge from Sicily. × 1060 linear, Page 45.

116. INTER-UMBONATE BIHAMATE.—When the umbo is on the middle of the inner curve of the shaft; from the same sponge as Fig. 115. × 1060 linear. Page 45.

117. BI-UMBONATE BIHAMATE.—When the middle of both the inner and outer curve of the shaft have an umbo. From the same sponge as Fig. 115. × 1060 linear. Page 45.

118. UNICLAVATE BIHAMATE.—I believe to be an arrest of development rather than a separate form; for although I found many specimens of it intermixed with the biclavate forms, I also found others assuming transitional forms, that appeared ultimately to connect it with the biclavate spicula. × 1060 linear. Page 44.

Fig.

119. Biclavate bihamate.—There is a considerable varia-
120. tion in the shape of this spiculum. The form represented by Fig. 119 is perhaps the most numerous, but that of Fig. 120 is the largest and most fully developed. × 1060 linear. Page 44.

121. Bicalcarate bihamate. × 1250 linear.—This singular and minute form of spiculum has hitherto been found only in *Isodictya Normani*, Bowerbank.

122. Quadrihamate. From *Hyalonema mirabilis*, Gray. × 1250 linear.—They are dispersed in considerable numbers on the interstitial membranes of the sponge.

123. Unipocillated bihamate. × 1060 linear.—One termination fully developed in the form of a cup, while the other is only produced to the extent of the two lateral curves, and a terminal umbo to the shaft. *Halichondria Hyndmani*, Bowerbank. Page 44.

124. Simple bipocillated bihamate.—× 1060 linear. Having both terminations developed in the form of cups in coincident planes. *Halichondria Hyndmani*, Bowerbank. Page 44.

125. Contort bipocillated bihamate. × 1060 linear.—Two cups being developed, but in planes at right angles to each other. *Halichondria Hyndmani*, Bowerbank. Page 44.

126. Umbonated bipocillated bihamate. × 1060 linear.—Having a slight prolongation of the shaft through the distal edge of one or both of the cups; in this case through the distal edge of the lower one only. *Halichondria Hyndmani*, Bowerbank. Page 29.

127. A view in profile of a unipocillated spiculum, × 1060 linear: the upper part of the figure represents a side view of the cup, while the termination of the lower portion is more than usually elongated; showing how the umbonation is produced on the distal edge of the spiculum, represented by Fig. 126, *Halichondria Hyndmani*, Bowerbank. Page 44.

FIG.

128. EXPANDO-TERNATE. × 108 linear.—From a portion of the skeleton of a sponge nearly allied to *Ecionemia*, Bowerbank. The shaft acting as a skeleton spiculum, while the apex serves as an external defence. Locality unknown.

129. INCURVO-PORRECTO-TERNATE. × 108 linear.—From the same sponge as Fig. 128. The shaft belonging to the skeleton, and the ternate apex acting as an external defence.

130. BIFURCATED EXPANDO-TERNATE. × 108 linear.—From the same sponge as Fig. 128. The shaft of the spiculum assisting in the formation of the skeleton, while the ternate terminations act as external defences.

131. INEQUI-TRIROTULATE. × 660 linear.—(See Plate X.) Having two terminal rotulæ of equal size, and one intermediate of greater diameter than the terminal ones. I have no knowledge of the sponge from which this spiculum is derived.

132. INEQUI TRIROTULATI. × 660 linear.—(See Plate X.) From an undescribed sponge in the cabinet of my friend Mr. George Clifton, Freemantle, Western Australia. This and the following two forms are abundant on the interstitial membranes of the sponge, and vary in form and extent of development exceedingly.

133. ECCENTRIC TRIROTULATE. × 660 linear.—(See Plate X.) From the same sponge as 132. This specimen is both centrical and eccentrical to a certain extent. Page 45.

134. ECCENTRIC TRIROTULATE. × 660 linear.—(See Plate X.) Exhibiting the fully-developed axial eccentricity. Page 45.

135. TORQUEATO-TRIDENTATE INEQUI-ANCHORATE. × 400 linear.—From a circular group on the interstitial membranes of an undescribed species of *Hymeniacidon*, from Freemantle, Australia. Page 49.

FIG.

136. TORQUEATO-BIDENTATE INEQUI-ANCHORATE. × 308 linear.—From an undescribed species of sponge. Freemantle, Western Australia.

137. BIDENTATE INEQUI-ANCHORATE. × 660 linear.—From an undescribed species of sponge from the coast of Sicily. Page 46.

138. PALMATED INEQUI-ANCHORATE. From an undescribed sponge. × 660 linear.—Having the distal termination largely developed in the form of a cordate palm, while the proximal end is produced to a much less extent, is compressed laterally, and has the terminal point expanded into a short broad tooth. Pages 46, 47.

139. DENTATO-PALMATE INEQUI-ANCHORATE, from *Spongia lobata*, Montagu; *Isodictya lobata*, Bowerbank. × 1060 linear.—Having the distal spatulate palm produced to the extent of about half the length of the spiculum, while the proximal one is developed in the same form to only about one-fourth the length of the spiculum, and having the apices of the hami produced beyond the extremities of the palms, each in the form of a short obtuse tooth. Sponge in the collection of Professor Grant.

140. TRIDENTATE EQUI-ANCHORATE. × 660 linear.—Having each termination equally and fully developed, in the form of two lateral and slightly palmate, and one central attenuated tooth. From an undescribed sponge in the collection of Mr. George Shadbolt. Page 47.

141. 142. 143. DENTATO-PALMATE ANGULATED ANCHORATE. × 1060 linear.—I have found this form of spiculum only in *Spongia plumosa*, Montagu. Each of the hami appears as if forcibly compressed towards the termination of the shaft, which seems to have been equally influenced by the compression, so that the hami have become angulated, as represented in the profile view of one of the spicula. Fig. 143. The whole of the spicula are dentato-palmate, and the

FIG.

adult ones have the terminations of the hami strongly produced, as represented in Fig. 141, while in the immature spicula, although the palms are fully produced, the tooth appears in a rudimentary condition, as Fig. 142, Pages 46 and 47.

144. DENTATO-PALMATE INEQUI-ANCHORATE. × 260 linear.—First stage of development. Page 48.

145. DENTATO-PALMATE INEQUI-ANCHORATE, second stage of development. × 260 linear. Page 48.

146. DENTATO-PALMATE INEQUI-ANCHORATE, third stage of development. × 260 linear. Page 48.

147. DENTATO-PALMATE INEQUI-ANCHORATE, an adult spiculum, showing the fully-produced distal terminal hastate tooth. × 260 linear. Page 47. See also Fig. 297, Plate XVIII, for the same form of spiculum *in situ*, from *Hymeniacidon lingua*, Bowerbank. × 308 linear.

148. DENTATO-PALMATE INEQUI-ANCHORATE.—From the same sponge as Fig. 147, showing the effects of incomplete development or malformation. × 260 linear.

149. EXPANDO-TRIDENTATE EQUI-ANCHORATE. × 1250 linear.—From an undescribed sponge in the British Museum. The shaft is frequently curved to the extent of nearly a semicircle. Expando-bidentate forms are mingled with the tridentate ones.

150. TRIDENTATE FIMBRIATED EQUIANCHORATE. × 660 linear.—From *Isodictya fimbriata*, Bowerbank, Shetland. The spicula of this form may be traced from the earliest stage of development, with scarcely a trace of fimbriation to the adult spiculum. Fig. 150. They are very abundant on the interstitial and dermal membranes, and mixed with them there are many that are only bidentate, but which are as completely fimbriated as the tridentate ones. The fimbriæ are very delicate and translucent, and require a careful management of the light to render them apparent.

FIG.

151. BIPOCILLATED EQUI-ANCHORATE. × 1166 linear.—See Plate XXXVII. Each termination of the shaft is developed equally in the form of a cup. They are abundantly dispersed in a recumbent position on the interstitial membranes of the sponge. From an undescribed species of *Desmacidon*, which I received from my late friend, Mr. Thomas Ingall. Locality unknown.

152. NAVICULOID SPICULUM. × 660 linear.—See Plate XXXVII. From a new species of *Hymedesmia* in the cabinet of Geo. Clifton, Esq., Freemantle, Western Australia. I received a small portion of the sponge mounted in Canada balsam. The spicula are abundantly dispersed over the interstitial membranes of the sponge, but principally in the vicinity of the skeleton fasciculi. They vary to some extent in form, but the one figured represents the general structure. A keel like rib may occasionally be observed, in addition to the two marginal ones; and the depth of the depression from the plane of the marginal ribs is much greater in some than in others. The nearest alliance in form to this spiculum appears to be that of the tridentate fimbriated equi-anchorate represented by Fig. 150. Plate XXXVII.

153. CYLINDRO-CRUCIFORM. × 175 linear.—From *Hya-*
154. *lonema mirabilis*, Gray, British Museum. The
155. four forms indicated by the above numbers occur
156. abundantly on the membranes immediately surrounding the thick coriaceous sheath which envelops the spiral column that is projected from the base of the sponge through its centre. All the imaginable varieties of form between Figs. 153 and 156 are found mixed together; and they appear to be especially abundant around that part of the column which is imbedded in the midst of the sponge. The cylindrical form represented by Fig. 153, is of

FIG.

rare occurence, without a slight indication near the middle, of the absent third and fourth rays of the perfect cruciform spiculum.

157. SPICULATED CYLINDRO-CRUCIFORM. × 174 linear.—From *Hyalonema mirabilis*, Gray, British Museum. This spiculum is from the sheath of the same sponge as those represented by Figs. 153 to 156. The ordinary cruciform spiculum being converted into an external defensive one by the projection of a spicular ray from its centre.

158. ATTENUATO-STELLATE. × 660 linear.—Having the radii gradually attenuated from the base to the apex. *Pachymatisma Johnstonia*, Bowerbank, affords a large and very excellent type of this form of spiculum. The radii vary from three to seven or eight, but five or six rays are the most common numbers. Page 51.

159. CYLINDRO-STELLATE, from *Pachymatisma Johnstonia*, Bowerbank. × 660 linear.—Having the radii of nearly equal diameter throughout, and terminating hemispherically. This form also occurs abundantly in *Tethia robusta*, Bowerbank, MS. The sponge is in the British Museum, and was brought from Australia by Mr. S. Stutchbury. The form and proportions of these spicula vary considerably; sometimes the distal terminations of the radii are slightly inclined to be clavate, and at others there is a gradual transition from simply stellate to sub-sphero-stellate. The radii are also in some of the larger specimens slightly inclined to attenuation.

160. CRASSATO - CYLINDRO - STELLATE. × 1060 linear.—This spiculum is remarkable from its having the radii twice as broad as they are thick, and their distal terminations abruptly truncated. It occurs intermixed with the more regular forms of cylindro-stellate in *Tethea robusta*.

FIG.

161. CLAVATED SUBSPHERO-STELLATE. × 1060 linear.—The cylindrical radii having the distal terminations more or less dilated, and the central basal sphere not exceeding in diameter the length of one of the radii. This form of spiculum is very abundant in *Tethea Ingalli*, Bowerbank, MS., intermingled with attenuato-cylindro-stellate spicula.

162. CLAVATED SPHERO-STELLATE. × 1060 linear.—The cylindrical radii having the distal terminations dilated, and the central basal sphere greater in its diameter than the length of one of the rays. This spiculum is abundant in the sarcode of the dermal and interstitial membranes of *Geodia Barretti*, Bowerbank, MS. It is very minute, the extreme diameter varying from $\frac{1}{3000}$th to $\frac{1}{7000}$th of an inch. Page 52.

—. ELONGO-ATTENUATO-STELLATE, from *Tethea muricata*, Bowerbank, MS. × 1060 linear.—See Fig. 35, Plate I, and corresponding description.

163. ARBORESCENT ELONGO-SUBSPHERO-STELLATE. × 106 linear.—(See Plate X.) Having the radii springing from a dilated and elongated common base of about the dimensions of two subsphero-stellate spicula, partially fused together.

This remarkable form occurs abundantly in *Geodia carinata*, Bowerbank, MS., from the South Sea. The nucleus, whence the radii proceed, is always more or less elongated, but is not usually so much dilated as in the specimen figured. The arborescent character of the distal terminations of the radii is also very variable.

164. SUBSPHERO-STELLATE. × 660 linear.—Having the radii more or less acutely conical, and as long or longer than the diameter of the central basal sphere: from *Tethea Ingalli*, Bowerbank, MS. In this sponge and in other species this form occasionally presents a very gradual transition from the purely stellate form to the full subsphero-stellate one, in

FIG.

which the radii and the spherical centre are of about equal length, while in the fully developed sphero-stellate forms this graduation is never seen. Pages 51, 52.

165. SPHERO-STELLATE. × 660 linear.—Having the radii acutely conical and based on a large central sphere of greater diameter than the length of the radii. *Tethea robusta*, Bowerbank, MS., a new species from Australia, in the British Museum, presents an excellent type of this form of spiculum. As the central nucleus appears, under favorable circumstances, we distinctly trace a central canal in each ray, passing from the centre of the sphere to near the distal termination of each of the radii, as represented in Fig. 167. These canals are not usually apparent in the perfect spicula, probably in consequence of the fluid being hermetically sealed within the canals of the radii, but I could not determine the presence of the fluid by polarized light. Pages 51, 52.

166. SPHERO-STELLATE WITH CYLINDRO-SUBFOLIATE RADII. × 400 linear.—Having the cylindrical radii slightly expanded and somewhat foliated at the distal extremities. This remarkable form was obtained by washing some specimens of *Oculina rosea* from the South Sea, and there is little doubt of its being from an unknown species of *Tethea*. Page 52.

167. A SPHERO-STELLATE SPICULUM, exhibiting the central canals in the radii. × 660 linear. Page 52.

168. PILEATED CYLINDRO-STELLATE. × 660 linear.—
169. Having several recurved spines uniting and forming
170. a pileus at the apex of the ray, shaped like that of
171. a young mushroom. These singularly variable spicula are abundant in *Spongilla plumosa*, Carter. They are remarkable as affording a series of transitional forms from a single straight spiculum to the regular multiradiate stellate one. Fig. 168 repre-

FIG.

sents, about the first stage of variation from the simple elongate spinous spiculum, a few rather strongly produced cylindrical spines appearing near the middle of the shaft. In Fig. 169, two of these spines are considerably more elongated than those in Fig. 168, and the shaft is not so long as in that figure. In Fig. 170 the axial shaft is still more curtailed in its proportions, and the central radii are further elongated and increased in number; and in Fig. 171 we find the axial spiculum scarcely distinguishable from the lateral rays. When the radii projected are few in number, they are usually at right angles to the axial spiculum; but when they are produced in greater numbers, they are projected at various angles, and the axial spiculum can scarcely be detected. In spicula having numerous radii, they frequently unite at their bases, and produce their extreme variation of form, a subsphero-stellate spiculum. No two of these singular spicula are alike, and they present every imaginable variation in the mode of their development. In their origin from an axial spiculum, and in their tendency to the projection of secondary radii at right angles to that axis, these spicula form a connecting link between the simple multiradiate forms and the more complicated ones belonging to the compound stellate spicula.

172. EXTER-SPINULATED ARCUATE. ×1250 linear.—From a small, massive sponge from the Bahamas, presented to me by my friend Mr. McAndrew. They are very abundantly dispersed over all parts of the interstitial membranes, are uniform in size, and vary to some extent in the degree of spiculation.

173. SUBSPINULATO-ARCUATE. 260 linear.—Abundantly dispersed on the interstitial membranes of a new species of sponge from Freemantle, Western Australia; sent to me by my friend Mr. Geo. Clifton.

COMPOUND STELLATE SPICULA.

Fig.

174. Attenuated rectangulated hexradiate. × 90 linear.—From *Euplectella aspergillum*, Owen. A fully developed spiculum. Page 52.

175. Attenuated rectangulated hexradiate. × 90 linear.—From the same sponge as Fig. 174. In an early stage of development, exhibiting only the primary or axial radii. Page 52.

176.
177.
178. Progressive degrees of development of the secondary radii of the same form of spiculum represented by Fig. 174. × 90 linear. Page 52.

179. The same spiculum as Fig. 175, with one secondary ray fully developed. × 90 linear. Page 52.

180. The same spiculum as Fig. 175, having two secondary rays forming a right angle with each other, fully developed. × 90 linear. Page 53.

181. The same spiculum as Fig. 175, with two secondary rays developed in opposite directions. × 90 linear. Page 53.

182. The same spiculum as Fig. 175, with three secondary rays forming two right angles with each other. × 90 linear. Page 53.

183. The same form of spiculum as Fig. 174, with the whole of the secondary radii fully developed, but with one only of the axial radii produced. × 90 linear. Page 53.

184. Slender attenuated rectangulated hexradiate. From *Euplectella aspergillum*, Owen. × 90 linear. Page 54.

185. Cylindro-rectangulated hexradiate, apically spined. From a specimen of *Alcyoncellum*, Quoy et Gaimard, in the Museum of the Jardin des Plantes, Paris. × 130 linear. Page 54.

FIG.

186. One of the radii of the spiculum represented by Fig. 185, exhibiting the spination of the apices. × 400 linear.

187. Part of the axial shaft of a cylindro-rectangulated hexradiate spiculum, exhibiting the parts from which the radii would be produced, from the *Alcyoncellum* in the Museum of the Jardin des Plantes, Paris. × 400 linear. Page 54.

188. BIFURCATED RECTANGULATED HEXRADIATE STELLATE. From the same *Alcyoncellum* as Fig. 187, in the Museum of the Jardin des Plantes, Paris. × 1060 linear.—It is minute and slender, and the bifurcating rays are irregular, often tortuous, and are frequently not produced on one or two of the primary radii. These indecisive characters, common to all the specimens of this form that I have seen, combined with the elongate characters of the radii, seem strongly to mark this spiculum as the connecting link between the simple hexradiate and the compound stellate forms of spicula. Page 55.

189. TRIFURCATED ATTENUATO-HEXRADIATE. From *Euplectella aspergillum*, Owen, having the ray nearest the eye broken off at its base. × 1060 linear.—The central radii consist of six rectangulated primary rays of equal length, each of which terminates in three equidistant secondary attenuating rays, which are projected from the apices of the primary ones at an angle of about 45 degrees to the common basal, or primary ray.

These spicula occur in abundance in *Euplectella aspergillum*, Owen, and in *Dactylocalyx pumicea*, Stutchbury. Page 55.

190. SPINULO-TRIFURCATED HEXRADIATE STELLATE. From *Dactylocalyx pumicea*, Stutchbury, a perfect spiculum. × 1060 linear. Page 55.

Fig.

191. Spinulo-quadrifurcate Hexradiate stellate. × 1060.—A rectangulated hexradiate spiculum, having each primary ray terminating in four nearly equidistant cylindro-spinulate secondary radii.

These spicula occur abundantly in a beautiful and unique specimen of a cup-shaped siliceo-fibrous sponge formerly in the cabinet of my friend Mr. Thomas Ingall, now in the British Museum. The remains of the sarcode are crowded with them in a perfect state of preservation. The specimen represented by Fig. 2 has had three of its primary radii broken off near their common base, thus enabling us to see distinctly the structure of this curious and beautiful form of spiculum. Page 55.

192. Spinulo - multifurcate hexradiate stellate. × 660 linear.—This spiculum forms a connecting link between the spinulo-quadrifurcate hexradiate stellate form and the floricomo-stellate one. A careful examination of the specimen presents indications of there having been as many as eight secondary radii at the termination of the primary ray which exhibits the greatest number of secondary ones in the figure, and it is probable that this was the full complement of those parts. Sponge unknown. Page 55.

193. Floricomo - hexradiate.—From *Euplectella aspergillum*, Owen, in the cabinet of Mr. Hugh Cuming, showing four out of the six primary radii, and the mode of the attachment of the secondary ones to their distal terminations. × 660 linear. Page 55.

194. Floricomo-hexradiate.—From the same sponge as Fig. 193, exhibiting a front view of the congregated expanded apices of one of the groups of the secondary radii, and the contour of a perfect spiculum. × 660 linear. Page 55.

Fig.

195. Coronato-hexradiate stellate.—From a species of *Alcyoncellum* in the Museum of the Jardin des Plantes, Paris. × 1060 linear.—The central radii consist of six rectangulated primary rays of equal length, each terminating in a discoid expansion, the margin of which is furnished with numerous curved petaloid radii.

196. Pociliated hexradiate stellate. × 1060 linear. The central radii consist of six rectangulated primary rays of equal length, each terminating in a concavo-convex disc or cup, the convex surface being outward.

I found this extremely minute form entangled in the tissues of a specimen of *Halichondria incrustans*, dredged up by my friend Mr. McAndrew at the Orkney Islands, and it is probably from one of the small species of *Alcyoncellum* that are found in the North Sea.

197. Dentato-cylindro-hexradiate. × 660 linear. (See Plate X.)—From a unique and very beautiful branching sponge from Nichol Bay, Australia, sent to me by my friend, Mr. Geo. Clifton, of Freemantle. The dentation of the radii of these spicula varies considerably in form and size; the number of teeth at the apices of the rays is usually two or three, occasionally four, and very rarely five. The spicula are nearly uniform in size and are extremely abundant in all parts of the interstitial membranes.

198. Attenuato-rectangulated triradiate: apically spined. × 90 linear.—This form is not, as it might be hastily surmised, the triradiate stage of development of a hexradiate spiculum. It is larger in every respect than the slender variety of the hexradiate form, and less stout, but much longer than the stout variety of the hexradiate

FIG.

form previously described; and although intermingled with them and the other forms of spicula in *Euplectella aspergillum*, Owen, it is always readily to be distinguished by an experienced observer.

The spines are small but thickly dispersed over the apices of the radii for a short way down the shaft, and occasionally the apices of the radii are more or less clavate.

—. CYLINDRO-RECTANGULATED TRIRADIATE.—This form of spiculum is abundant in *Dactylocalyx pumicea*, Stutchbury. The basal axial ray is often very much elongated. The radii are also incipiently spined, and their apices are more or less spinulate or clavate. The form of this spiculum is precisely that of Fig. 198, excepting that the radii are cylindrical instead of attenuated.

199. SPICULATED BITERNATE. × 90 linear.—I found several of these spicula in the dust shaken from the siliceo-fibrous massive sponge *Farrea occa*, Bowerbank, MS., at the base of my friend Dr. A. Farre's specimen of *Euplectella cucumer*, Owen, and I have no doubt of their belonging to the sarcode of the sponge at its base. They appear to vary greatly in the amount of their development. In Fig. 199 the biternate spicula are simple, and it is spiculated at one end only. Some of them were similar to Fig. 199, but were spiculated at both ends.

200. FURCATED SPICULATED BITERNATE. × 130 linear.—From *Farrea occa*, Bowerbank, MS. These spicula are intermixed with those represented by Fig. 199. They vary considerably in size, and in the number of the rays which are furcated.

SPICULA OF THE OVARIES AND GEMMULES.

1st. Spicula elongate, disposed at right angles to lines radiating from the centre of the gemmule to its surface.

Fig.

201.
202. Acerate. × 30 linear.—This form occurs abundantly in the envelope of the ovary of *Spongilla Carteri*, Bowerbank, from the water-tanks of Bombay; and in *Sp. Brownii*, Bowerbank, from the River Amazon. In both these species the spicula of the ovaries agree in form with those of their respective skeletons, but are not more than half their size. Fig. 201, a spiculum of the envelope of the ovary of *Spongilla Carteri*. Fig. 202, a spiculum of the envelope of the ovary of *Spongilla Brownii*. Page 58.

203. Subarcuate acerate: entirely spined. × 660 linear.—The envelope of the ovary of *Spongilla lacustris*, Johnston, abounds in this form. The length and mode of spination of these spicula are nearly the same in all of them, but the amount of curvature varies from almost straight to nearly a semicircle, as represented by Fig. 203; and in one case the terminations of the spiculum have crossed each other, forming a loop. In some sponges the spicula of the ovaries agree in form with those of the dermal membrane, but this is not the case in the present instance, those of the membrane being slender fusiformi-acerate. Pages 38, 58, 137.

204. Fusiformi-acerate: entirely spined, spine cylindrical. × 660 linear.—These spicula are long, slender, and very slightly curved; they are dispersed abundantly in the envelope of the ovary of *Spongilla Batei*, Bowerbank, from the River Amazon.

FIG.

The spination of the spiculum is very remarkable; those near the middle of the shaft are frequently of a length equal to half or two-thirds the greatest diameter of the spiculum on which they are based. They are of the same diameter from the base to the apex, and terminate as abruptly as if they had been truncated. Page 38.

205. ACERATE: ENTIRELY SPINED, SPINES CONICAL. × 660 linear.—This form of spiculum occurs in the envelope of the ovary of *Spongilla cinerea*, Carter. It is very abundant and somewhat minute, and requires a linear power of about 600 to define it accurately. The spines are very numerous, and all of them appear to pass from the spiculum at right angles to its axis. The largest of them is about one-third the length of the greatest diameter of the spiculum.

206. CYLINDRICAL: INCIPIENTLY SPINED. × 400 linear. —This short stout form of spiculum occurs abundantly in the envelope of *Spongilla gregaria*, Bowerbank, from the River Amazon. It is usually without spines, but occasionally a few incipient ones are dispersed over the shaft.

207. CYLINDRICAL: ENTIRELY AND RECURVEDLY SPINOUS. × 400 linear.—This large and beautiful form of spiculum is abundant in the envelope of the ovary of *Spongilla alba*, Carter. It has a considerable amount of curvature, and the spination is remarkably bold and striking. Very few of the spines issue from the shaft at right angles to its axis, and these are always near its middle; the remainder of the spines are all curved from the apices of the spiculum towards the middle of the shaft. The spines are congregated in considerable numbers at each termination of the spiculum, and are larger and more curved there than on any other part of the shaft.

FIG.

—. CYLINDRICAL: ENTIRELY SPINED; SPINES OF THE MIDDLE CYLINDRICAL, THOSE OF THE TERMINATIONS CONICAL AND RECURVED.—These spicula might readily be mistaken by a hasty observer for those of *Spongilla alba*, but a closer observation exhibits essential differences in their mode of spination. They are very numerous in the envelope of the ovary of *Spongilla cinerea*, Carter, from the water-tanks of Bombay. They are so nearly of the same form as those represented by Fig. 207, as to render it unnecessary to figure them. Page 59.

2ND. SPICULA DISPOSED IN LINES RADIATING FROM THE CENTRE TO THE CIRCUMFERENCE OF THE OVARY.

Birotulate and Boletiform Spicula.

208. ADULT RECURVO-DENTATE BIROTULATE SPICULUM. Shaft entirely spined, from the ovary of *Spongilla plumosa*, Carter. × 660 linear. Pages 59—61.

209. A view of the inner surface of one of the rotulæ of the spiculum represented by Fig. 208, showing the amount and irregularity of the dentation of its margin. × 660 linear.

210. First stage of development of a birotulate spiculum from the ovary of *Spongilla plumosa*, Carter. × 660 linear. Page 61.

211. Second stage of development of a birotulate spiculum from the ovary of *Spongilla plumosa*, Carter. × 660 linear. Page 61.

212. Third stage of develepment of a birotulate spiculum from the ovary of *Spongilla plumosa*, Carter. × 660 linear. Page 61.

FIG.

213. BIROTULATE, MARGINS OF THE ROTULÆ ENTIRE.—From *Spongilla gregarea*, Bowerbank. A side view of an averaged-sized specimen. × 1100 linear. Page 137.

214. A view of the external surface of one of the rotulæ of the same form of spiculum as that represented by Fig. 213. × 1100 linear. Page 137.

215. A young imperfectly developed spiculum of the same description as represented by Fig. 213. × 1100 linear. Page 137.

216. A spiculum of the same description as represented by Fig. 213, developed to a greater extent than usual. × 660 linear. Page 137.

217. BIROTULATE, ROTULÆ IRREGULARLY AND DEEPLY DENTATE.—From *Spongilla fluviatilis*, Johnston. × 660 linear. Page 136.

218. A view of the external surface of one of the rotulæ of the same description of spiculum represented by Fig. 217. × 660 linear. Page 136.

219. BIROTULATE: ROTULÆ IRREGULARLY AND DEEPLY DENTATE, SHAFT MEDIALLY SPINED. × 660 linear.—This form occurs in the ovaries of *Spongilla Meyeni*, Carter, from the water-tanks of Bombay. It is the largest spiculum of that form that I have yet seen. It differs from the congenerous form in *Spongilla fluviatilis*, inasmuch as the spination of the shaft in *Sp. Meyeni* is the rule, while in *Sp. fluviatilis* it is a rare exception. Pages 59, 137.

220. MULTIHAMATE BIROTULATE. × 660 linear.—This singular form of spiculum is from the outer portion of the ovaries of *Spongilla recurvata*, Bowerbank, from the river Amazon.

The external surfaces of the rotulæ are smooth, very convex, and in many cases almost hemispherical; so that the points of the curved spines are in the direction of lines parallel to the shaft of the spiculum,

FIG.

and the rotulæ are cleft almost to the point of union with the shaft. The number of the curved spines vary; in one rotula there were as many as ten, but the usual number is five or six. An average-sized specimen measured $\frac{1}{1056}$th of an inch long; diameter of the rotulæ, $\frac{1}{1500}$th of an inch; and diameter of the shaft, $\frac{1}{4286}$th of an inch.

221. 222. INEQUI-BIROTULATE. × 660 linear.—This spiculum exhibits a gradual transition from the fully developed birotulate to the completely boletiform tribe of spicula. It occurs in *Spongilla paulula*, Bowerbank, from the River Amazon. It is a stout fully developed form, and the whole of them exhibited, as nearly as possible, the same proportions. From both terminations of the shaft a number of minute radial canals, represented in Fig. 222, pass from the centre to the circumference of the rotulæ, and in one of the large ones I counted twenty radial canals. The rotulæ are flat, or very slightly convex outward near the centre, and the margins are perfectly entire. Pages 60, 61, and 137.

223. BOLETIFORM. × 660 linear.—The form of this spiculum is very like that of the common edible mushroom when fully grown. The large discal end is convex externally, and has the margin entire. The shaft is nearly of the same diameter throughout its length, and occasionally it has one or two large spines projected from it, near the middle and at right angles to its axis.

The small end is more or less lentiform, but it is frequently very irregular both in size and shape. From the ovary of *Spongilla reticulata*, Bowerbank, River Amazon. Pages 60, 137.

224. 225. BOLETIFORM: SLENDER. × 660 linear.—This graceful and elegant form of spiculum occurs at the inner surface of the crust of the ovary of *Spongilla recurvata*, Bowerbank, from the River Amazon. The

FIG.

shaft is exceedingly slender, measuring at the middle $\frac{1}{25000}$th of an inch in diameter. The large discal end of the spiculum is slightly convex externally, has the margin perfectly entire, and is $\frac{1}{1027}$th of an inch in diameter. The small lentiform end measured $\frac{1}{6000}$th of an inch in diameter, and the total length of the spiculum is $\frac{1}{707}$th of an inch. Fig. 225 represents the inner surface of the rotula. Pages 60, 137.

226. UMBONATO-SCUTULATE. × 660 linear.—This spicu-
227. lum is found immediately beneath the outer membrane of the ovary of *Spongilla Brownii*, Bowerbank, from the River Amazon. The form is truly that of a little shield, the lower surface being concave, while the upper one has a corresponding degree of convexity, and the umbo projects from its centre in the shape of a small cone. The diameter of an average-sized one is $\frac{1}{1200}$th of an inch, and the height very nearly equalled the diameter. Fig. 227 represents a side view of the spiculum showing the length and form of the umbo. Page 60.

NEW FORMS OF SPICULA FOUND SINCE THE PRECEDING ONES WERE DESCRIBED AND FIGURED.

228. BISPINULATE. × 175 linear.—From *Halicnemia patera*, Bowerbank. Page 15.

229. TRISPINULATE. × 175 linear.—From *Halicnemia patera*, Bowerbank. Page 15.

230. The normal form of spinulate spiculum from the same sponge as the spicula represented by Figs. 228 and 229. × 175 linear. Page 15.

231. Undeveloped forms of spinulate, bispinulate, and
232. trispinulate, from the same sponge as the three pre-
233. ceding figures. × 175 linear. Page 15.

234. SPICULATED INEQUI-ANGULATED TRIRADIATE, with cylindrical entirely spined radii. × 308 linear.—From *Dictyocylindrus Vickersii*, Bowerbank, MS.

FIG.

From the West Indies? This spiculum is an external defensive one. The triradiate rays are imbedded immediately beneath the dermal membrane, and the spicular ray is projected through it at right angles to its plane; they are very numerous.

235. SPICULATED ATTENUATO-EQUIANGULAR TRIRADIATE: VERTICILLATELY SPINED. × 660 linear.—From an undescribed sponge. Freemantle, Western Australia. I have not seen the specimen whence this spiculum is derived, but, reasoning from our knowledge of the form and situation of the spiculum represented by Fig. 234, there can be little doubt of its being an external defensive one.

236. SPICULATED CYLINDRO-EQUIANGULAR VERTICILLATELY SPINED. × 660 linear. Freemantle, Western Australia. From the same slide of *Sponge spicula* in which the form represented by 235 was found. There can be little doubt of its being an external defensive organ.

237. INEQUI-FURCATO-TRIRADIATE. × 183 linear.—These spicula are from a new species of calcareous sponge, probably a Grantia. They were sent to me mounted in Canada balsam by my friend Mr. George Clifton, of Freemantle, Australia. They occur loosely fasciculated, and their mode of disposition is probably on the surface of the sponge. They differ considerably from each other in length and in the width apart of the prongs of the fork, but they all have them unequal in length. It is probably an auxiliary skeleton and external defensive spiculum.

238 and 239. ATTENUATO-CYLINDRICAL VERTICILLATELY SPINED. × 183 linear.—From *Hymeraphia verticillata*, Bowerbank. These spicula are dispersed in abundance on the interstitial and dermal membranes of the sponge. In the young state the spicular are long, slender, and perfectly smooth;

FIG.

in the course of their further development they assume a monilliform appearance, as represented by Fig. 239, and in their adult state are verticillately spined, as represented by Fig. 238.

240. INFLATO-ACERATE, with incissurate terminations. × 660 linear.—From *Hymeraphia verticillata*, Bowerbank. A terminal portion only of this spiculum is represented by the figure, the incissurate character being the only novelty in the form. The incissuration varies in degree to a considerable extent in different spicula, in some cases being very slightly produced, in others rather beyond that represented by the figure. The rudiments of a third ray are sometimes apparent. This form is an auxiliary skeleton spiculum. They are found thickly clustered round the primary spicula of the skeleton. They differ essentially from porrecto-ternate spicula in having both ends cleft or radiate, which is never the case in any of the ordinary ternate forms.

SPICULA, THE POSITIONS OF WHICH ARE UNKNOWN.

241. BIRECURVO-QUATERNATE, MEDIALLY SPINED. Sponge unknown, × 660 linear.—Probably an internal defensive spiculum.

242. SPINULATO-ENSIFORM, from a parasitical sponge from Western Australia. × 130 linear.—I obtained this singular form from a parasitical sponge from Western Australia. This curious sponge, in the formation of its skeleton, appears to have appropriated the spicula of every other kind of sponge that came within its reach.

243. ACUATE: BASALLY RECTANGULATED. × 150 linear. —I obtained this spiculum from the spongeous matter scraped from the base of *Oculina rosea*, by a dealer in the process of cleaning the coral. It is not a malformation, as there are several

FIG.

of them in the same slide, and they are all angulated to the same extent. It is probably an internal defensive spiculum.

244, 245, 246. TUBERCULATED FUSIFORMI - CLYINDRICAL.—The beautiful spiculum represented by Fig. 244, × 660 linear, is siliceous. It has been repeatedly found in the matter obtained by washing the roots of *Oculina rosea* and other corals from the South Sea, by my friends Messrs. Matthew Marshall, Legg and Ingall, but the sponge, whence it is most probably derived, has never yet been determined. It is remarkable as being the only well-defined and perfect siliceous spiculum that has yet been observed to possess the short stout tubercles that are so characteristic of its structure. Fragments of two other spicula, possessing similar characters, have been observed by me, and are represented by Figs. 245 and 246. In the specimen represented by Fig. 246, × 260 linear, the tubercles are less in number, but are considerably more produced, and their terminations are more abruptly truncated. In the spiculum represented by Fig. 245, × 260 linear, they are still more widely distributed, are shorter and more inclined to be conical, so that there is little doubt that they have belonged to three distinct species of sponge. But in all three of them there is one peculiarity, that of the manner of the disposition of the tubercles on the shafts of the spicula, where we observe them to be disposed in more or less regular longitudinal lines, and that the tubercles forming each line alternate with those of the line next to them, so that they assume the appearance of a spiral arrangement. The close alliance in the structure of these spicula would seem to indicate the existence of a peculiar tribe of sponges, with which we are at present entirely unacquainted.

ANATOMICAL STRUCTURE OF SPICULA.

Fig.

247. Distal termination of a porrecto-ternate spiculum from *Tethea cranium*, with angular distortions from external pressure. × 260 linear. Page 6.

248. A portion of an adult spiculum from *Spongilla fluviatilis*, charred to exhibit the thin membrane of the central cavity of the spiculum. × 260 linear. Page 6.

249. A portion of an immature spiculum from *Spongilla lacustris*, charred to exhibit the dense membrane lining the large central cavity in the young spiculum. × 260 linear.

250. A section at right angles to the axis of the upper part of the shaft of a ternate spiculum from *Geodia Barretti*, Bowerbank, MS., exhibiting the concentric layers. × 260 linear. Page 6.

251, 252. Portions of charred spicula from the skeleton fasciculi of *Tethea cranium*, exhibiting their hollow condition after incineration. × 90 linear. Page 8.

253. A portion of a spiculum from *Euplectella aspergillum*, Owen, slightly charred, exhibiting the concentric layers of silex. × 90 linear. Page 11.

254. A portion of an adult spiculum from the skeleton of *Geodia McAndrewii*, Bowerbank, MS., cracked by the application of cold water while in a heated state. × 90 linear. Page 9.

MEMBRANOUS TISSUES.

255. Fibro-membranous tissue. Containing a single layer of parallel fibres on a portion of the membrane from an excurrent canal of one of the common honeycomb sponges of commerce. × 660 linear. Pages 67, 99, and 100.

Fig.

256. Fibro-membranous tissue. From the dermal membrane of a Stematumenia. × 183 linear. Pages 100, 211.

257. Fibro-membranous tissue. In which the layers of fibre cross each other at about right angles. From *Alcyoncellum robusta*, Bowerbank. × 660 linear. Page 100.

258. Fibro-membranous tissue. In which the layers of fibre cross each other at various acute angles. From *Alcyoncellum robusta*, Bowerbank. × 308 linear. Page 100.

FIBROUS STRUCTURES.

PRIMITIVE FIBROUS TISSUE.

259. Primitive fibrous structures. Dispersed on the inner surface of a portion of the dermal membrane of a young Stematumenia; *a a*, cells *in situ*, which have each produced a fibre. × 660 linear. Page 70.

260. Detached specimens of primitive fibrous tissue. In progressive stages of development. × 660 linear. Page 70.

KERATOSE FIBROUS TISSUE.

261. Solid keratose fibre. From a cup-shaped specimen of the best Turkey sponge of commerce, in the condition in which it came from the sea. × 175 linear. Page 73.

262. Spiculated keratose fibre. From *Chalina oculata*, Bowerbank. × 175 linear. Pages 74, 208.

FIG.

263. SPICULATED KERATOSE FIBRE. From *Chalina Montagui*, Bowerbank, a young fibre in course of development (a) the apical spiculum. × 175 linear. Pages 74 and 108.

264. MULTISPICULATED KERATOSE FIBRE. From *Desmacidon ægagropila*, Bowerbank. × 108 linear. Page 75.

265. INEQUI-SPICULATED KERATOSE FIBRE. From *Raphyrus Griffithsii*, Bowerbank. × 175 linear. Pages 75 and 201.

266. SIMPLE FISTULOSE KERATOSE FIBRE. From *Spongia fistularis*, Lamarck. × 108 linear. Pages 76 and 209.

267. COMPOUND FISTULOSE KERATOSE FIBRE. From the skeleton-fibres of *Auliskia*, Bowerbank, exhibiting the secondary canals radiating from the primary ones. × 300 linear. Pages 77 and 210.

268. COMPOUND FISTULOSE KERATOSE FIBRES. From *Auliskia*, Bowerbank, exhibiting the general character of the fibre. × 100 linear. Pages 77 and 210.

269. REGULAR ARENATED KERATOSE FIBRE. From one of the Bahama sponges of commerce. × 175 linear. Page 77.

270. IRREGULAR ARENATED KERATOSE FIBRE. From *Dysidea fragilis*, Johnston, having the siliceous grains very abundantly packed in its substance. × 108 linear. Pages 78 and 211.

271. IRREGULAR ARENATED KERATOSE FIBRE. From *Dysidea fragilis*, Johnston, exhibiting its general character *in situ*. × 108 linear. Pages 78 and 211.

272. IRREGULAR ARENATED KERATOSE FIBRE, showing how the young fibre picks up the grain of sand and surrounds it with keratode. × 108 linear. Pages 63, 78, and 211.

273. HETRO-SPICULATED KERATOSE FIBRE. From *Diplodemia vesicula*, Bowerbank. × 175 linear. Pages 74 and 202. (See Plate XIV.)

Fig.

274. Smooth solid siliceous fibre. From *McAndrewsia*, Gray. × 175 linear. Pages 13, 79, and 204.

275. Tuberculated solid siliceous fibre. From *Dactylocalyx pumicea*, Stutchbury. × 108 linear. Pages 79 and 204.

276. Tuberculated solid siliceous fibre, very prominently tuberculated. From *Dactylocalyx Prattii*, Bowerbank, MS. × 175 linear. Pages 80 and 204.

277. Simple fistulose siliceous fibre, spinulated. From *Farrea occa*, Bowerbank, MS. × 108 linear. Pages 13, 80, and 204.

PREHENSILE FIBRE.

278. Cidarate prehensile fistulose siliceous fibre. From a parasitical siliceo-fibrous sponge from the south sea; showing the position of the prehensile organs at the base of the sponge. × 83 linear. Page 80.

FIBRILATED FIBRE.

279. Fibrilated sponge fibre. From the skeleton of one of the sponges of commerce. × 308 linear. Page 73.

280. Fibrilated sponge fibre. From one of the rigid Australian sponges. × 175 linear. Page 73.

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281. A group of cells on a piece of an interstitial membrane from *Ecionemia acervus*, Bowerbank, MS. × 660 linear. Pages 81 and 88.

282. Cells on a portion of the interstitial membrane of *Halichondria nigricans*, Bowerbank. × 308 linear. Pages 82 and 88.

FIG.

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284. A view of the upper stratum of cells in one of the Ovaria of *Spongilla Carteri*, Bowerbank. × 308 linear.
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SARCODE.

285. Represents a small piece of an interstitial membrane from the honeycomb sponge of commerce in the condition in which it came from the sea, exhibiting the sarcode *in situ* and the imbedded semi-digested molecules of nutriment. × 660 linear. Page 88.

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287. A portion of a thin section at right angles to the surface of a specimen of *Chalina seriata*, Bowerbank, illustrating the mode of external defence by the prolongation of the radial lines of the skeleton. × 108 linear. Page 24.

288. A small portion of the kerato-fibrous skeleton of an Australian sponge, showing the attenuato-acuate entirely spined internal defensive spicula *in situ* dispersed on the skeleton fibre. × 108 linear. Page 31.

289. Verticillately spined internal defensive spicula dispersed on keratose fibres of the skeleton, from a West Indian sponge. × 175 linear. Pages 23 and 125.

FIG.

290. Verticillately spined internal defensive spicula from a keratose sponge, from the West Indies. Congregated in fasciculi. × 175 linear. Pages 31 and 125.

291. A small portion of *Hymeniacidon Cliftoni*, Bowerbank, MS., exhibiting the membranous tissues of the sponge enveloping the fibres of a Fucus; the defensive spicula over the fibre being erect, whilst those on the adjoining membrane are recumbent. × 108 linear :—*a*, one of the attenuato-cylindrical internal defensive spicula. × 260 linear; *b*, a small portion of the surface of the Fucus showing its cellular structure. × 400 linear. Pages 31 and 125.

292. A portion of the reticulated specimen of the sponge with the radiating fasciculi of spinulo-quaternate internal defensive spicula *in situ*. × 108 linear. See also Fig. 76, Plate III. Pages 23, 33, and 122.

293. A portion of the reticulated skeleton of *Hymedesmia Johnsoni*, Bowerbank, MS., from Madeira, the fibres armed with trenchant contort bihamate spicula. × 50 linear. One of the trenchant contort bihamate spicula, showing the cylindrical form at the curves of the hook and the middle of the shaft, and the trenchant edges of the rest of the inner surfaces of the spiculum, × 400 linear, is represented by Fig. 112, Plate V. Pages 35 and 127.

294. A portion of the skeleton of *Hyalonema mirabilis*, Gray, showing the mode of disposition of the multihamate birotulate and spiculated cruciform spicula in the body of the sponge. In the collection at the British Museum. × 50 linear. One of the multihamate birotulate, × 175 linear, is represented by Fig. 60, Plate III, and Fig. 294, Plate XVIII. Pages 37 and 127.

295. Represents a spiculated cruciform spiculum from the same sponge, to show the relative proportions of the two forms of defensive spicula. × 175 linear. Pages 37 and 127.

FIG.

296. Represents a small portion of the inner surface of the dermal membrane of *Hymedesmia Zetlandica*, Bowerbank, showing the fasciculation of the simple bihamate spicula, the equi-anchorate ones dispersed singly on the membrane and the large attenuato-acuate entirely spined defensive ones *in situ*. × 308 linear. Pages 44 and 190.

297. A circular group of inequi-anchorate spicula, situated on one of the interstitial membranes of *Hymeniacidon lingua*, Bowerbank. × 308 linear. See also Figs. 138, 147, &c., Plate VI. Page 49.

298. A small portion of the dermal membrane from *Dictyocylindrus stuposus*, Bowerbank, exhibiting the number and position of the minute sphero-stellate defensive spicula with which it is armed. × 308 linear. Page 109.

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300. A section of *Halinchondria panicea*, Johnston, showing the intermarginal cavities at *a*, immediately beneath the dermal surface. × 108 linear. Pages 100 and 195.

301. View of a small portion of the inner surface of the dermal crust of *Geodia Barretti*, Bowerbank, MS., with two of the valvular membranes of the proximal ends of the intermarginal cavities:—*a*, valve closed; *b*, a valve partly open; *c*, *c*, the radii of the patento-ternate spicula, imbedded in the tissues, and forming the areas for the support of the valvular terminations of the intermarginal cavities. × 50 linear.—Longitudinal sections of two of the intermarginal cavities are shown at *a*, *a*, Fig. 354. Plate XVIII.

Dermal membrane and inhalent pores, pages 111 and 173.

FIG.

302. Two groups of inhalent pores in the dermal membrane, situated immediately above the distal ends of the intermarginal cavities of *Geodia Barretti*. ×83 linear. Page 171.

303. A portion of the dermal surface of *Halichondria panicea*, Johnston, showing the multispicular network for the support of the dermal membrane and the open pores in the areas. × 108 linear. Pages 108 and 195.

304. A small portion of the dermal membrane of *Tethea muricata*, Bowerbank, MS., exhibiting the pores in an open condition. × 108 linear. Pages 25 and 108.

305. A small portion of the same piece of membrane, highly magnified, to show the positions of the elongo-stellate defensive spicula on the external surface of the dermal membrane. × 183 linear. Pages 25 and 108.

306. Represents the inner surface of the dermis of *Dactylocalyx Prattii*, Bowerbank, MS., showing the manner in which the apices of the radii of the ternate spicula forming the inhalent porous areas, are spliced on each other to allow of the expansion and contraction of the dermal surface. × 108 linear. Pages 18, 19 and 101.

307. Represents a portion of the dermal surface of an undescribed sponge from the East Indies, having numerous depressed porous areas furnished with stomata-like protective organs, *a*, the protective organ in a perfect condition; *b*, having the protective organ removed to exhibit the deeply depressed porous area. × 50 linear.

308. A portion of the sponge represented of its natural size, with two large oscula and numerous inhalent areas.

309. A small portion of the single-seried dermal spicular network of *Isodictya varians*, Bowerbank. × 108 linear. Page 108.

FIG.

310. A piece of reticulated kerato-fibrous tissue supporting the dermal membrane of one of the species of the common West Indian sponges of commerce. × 108 linear. Pages 108, 109.

311. A small portion of the quadrilateral siliceo-fibrous network of the dermis of *Farrea occa*, Bowerbank, MS., showing the double series of entirely spined spicular organs projected from its angles. × 108 linear. Page 104.

CILIA AND CILIARY ACTION.

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313. A view of a small portion of the inner surface of *Grantia compressa*, exhibiting the oscula open, and the appearance presented at their orifices by the cilia within in action. × 500 linear. Pages 105, 129, 130 and 163.

314. Detached cilia and tessellated cells from the interior of the intermarginal cavities of *Grantia compressa*. × 1250 linear. (*a*) A cilium in repose. (*b*) One in the position of action. (*c*) Detached cells. Pages 82 and 129.

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315. A small piece of a fibre of the skeleton of one of the common Bahama sponges of commerce, with numerous ova imbedded in its surface. × 400 linear. Pages 81 and 134.

316. A small piece of the fibre represented by Fig. 315, exhibiting the varieties in form and proportion of the ova. × 1250 linear. Pages 81 and 134.

FIG.

317. An ovarium of *Spongilla fluviatilis* in its natural state, exhibiting the foramen. × 83 linear. Page 132.

318. A perfect skeleton of an ovarium of *Spongilla fluviatilis*, Johnston, prepared with nitric acid. × 183 linear. Pages 60 and 136.

319. View of a section, at right angles to the surface, of a fragment of the skeleton of the ovarium of *Spongilla fluviatilis*, prepared with nitric acid, exhibiting the relative positions of the spicula in the skeleton. (*a*) A spiculum detached from the same ovarium × 308 linear. Pages 60 and 136.

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321. Two of the reticulated cases of the ovaria of *Spongilla Brownii*, Bowerbank:—*a*, an empty case; *b*, a case containing the skeleton of an ovarium. × 50 linear. Page 139.

322. A reticulated case of an ovarium of *Spongilla reticulata*, Bowerbank. × 175 linear. Page 138.

323. Skeleton of an ovarium of *Spongilla reticulata*, Bowerbank, without its case, prepared with nitric acid. × 175 linear. Page 138.

324. A perfect ovarium of *Diplodemia vesicula*, Bowerbank, and a portion of a second one, showing the interior and the thickness of its walls in its natural state. × 83 linear. Pages 60 and 140.

325. An ovarium of *Geodia McAndrewii*, Bowerbank, MS., in very nearly an adult state, showing the structure and position of the conical foramen for the discharge of the ova, natural condition. × 183 linear. Page 142.

FIG.

326. A small portion of the surface of a fully-developed ovarium of *Geodia McAndrewii* in its natural state, showing the distal ends of the spicula flat and angular, and firmly cemented together. × 308 linear. Page 142.

327. Two ovaria of *Geodia McAndrewii*, (*a*) containing about the maximum of ova, (*b*) after a great part of the ova have been discharged. × 108 linear. Page 141.

328. A portion of a section through nearly the centre of a mature ovarium of *Geodia McAndrewii*, showing the radiation of its spicula from near the centre to its circumference. × 308 linear. Page 142.

329. A portion of a young ovarium of *Geodia McAndrewii*, with the distal ends of its spicula acutely terminated, and unconnected. × 308 linear. Page 142.

330. A mature ovarium of *Pachymatisma Johnstonia*, Bowerbank, exhibiting the cuneiform spicula of the foramen. × 308 linear. Page 143.

331. A young ovarium of *Pachymatisma Johnstonia* in course of development. × 308 linear. Page 143.

332. A young ovarium of *Pachymatisma Johnstonia* in a very early stage of development. × 308 linear. Page 143.

333. An ovarium from a sponge from Madeira closely allied to *Pachymatisma*, exceedingly depressed and much elongated. × 308 linear. Page 143.

334. A fragment of a similar ovarium to that represented by Fig. 333, the fracture showing its extremely thin condition. × 308 linear. Page 143.

335. A young ovarium of the same species as that represented by Fig. 333, in an early stage of development. × 308 linear. Page 143.

FIG.

336. A reticulated ovarium *in situ*, on the fragment of a sponge from Madeira. × 108 linear. Page 144.

337. A portion of the reticulated structure from an ovarium of the same description as represented by Fig. 336. × 308 linear. Page 144.

338. An ovum in course of development into a young sponge on the same membrane as that on which the ovarium represented by Fig. 336 is seated. × 108 linear. Page 144.

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341. A gemmule detached from *Iphiteon panicea*. × 660 linear. Page 204.

342. A gemmule extruded from near the base of a specimen of *Tethia lyncurium*, on the distal extremity of one of the skeleton fasciculi. × 50 linear. Page 149.

343. Part of a group of internal gemmules *in situ*, on the interstitial membranes of *Tethea cranium*:—*a*, one of the larger and most completely organized gemmules; *b*, one of the smaller and more simple gemmules which always accompany the larger ones. In Canada balsam. × 108 linear. Page 148.

344. One of the larger description of gemmules of *Tethea cranium*, in its natural state, removed from the membrane and viewed by direct light. × 25 linear. Page 148.

ILLUSTRATIONS OF THE GENERA.

Order I.—*Calcarea.*

Fig.

345. Grantia. A longitudinal section of a portion of one side of a specimen of *Grantia ciliata*, Johnston, exhibiting the structure and mode of disposition of the interstitial cells. × 108 linear. See also Fig. 312, Pl. XXI, for the interstitial cells of *G. compressa.* Pages 27, 119, and 163.

346. A group of two *Grantias* on a Zoophyte, natural size; *a*, *G. ciliata*, *b*, *G. compressa.* Page 163.

347. Leucosolenia botryoides, *Bowerbank.* Two branches exhibiting the simple fistulose structure of the sponge. × 50 linear. Page 164.

348. A small group of the sponges *L. botryoides*, natural size. Page 164.

349.—Leucogypsia Gossei, *Bowerbank.* A section at right angles to the surface, exhibiting the mass of irregular interstitial structure. × 50 linear. Page 166.

350. A specimen of *L. Gossei*, natural size, exhibiting the form and position of the oscula. Page 166.

351.—Leuconia nivea, *Bowerbank.* A longitudinal section of one of the mammiform portions, exhibiting one of the great cloacal cavities of the sponge and its internal defensive spicula. × 50 linear. Page 165.

352. An averaged-sized specimen of *L. nivea*, exhibiting the lobular form of the cloacal portions of the sponge and the position of the mouths of the cloacæ. Page 165.

Order 2.—SILICEA.

Sub-order 1.

FIG.

353. PACHYMATISMA JOHNSTONIA, *Bowerbank*. A section at right angles to the surface, exhibiting the irregularity of the interstitial structures directly beneath the dermal crust. × 50 linear. Page 172.

354. GEODIA BARRETTI, *Bowerbank*, MS. A section at right angles to the surface, exhibiting the radial disposition of the fasciculi of the skeleton, and a portion of the dermal crust of the sponge. × 50 linear. —*a*, intermarginal cavities; *b*, the basal diaphragms of the intermarginal cavities; *c*, imbedded ovaria forming the dermal crust of the sponge; *d*, the large patento-ternate spicula, the heads of which form the areas for the valvular bases of the intermarginal cavities; *e*, recurvo-ternate defensive and aggressive spicula within the summits of the great intercellular spaces of the sponge; *f*, portions of the interstitial membranes of the sponge, crowded with minute stellate spicula; *g*, portions of the secondary system of external defensive spicula. Pages 122, 169 and 171.

355. ECIONEMIA ACERVUS, *Bowerbank*, MS. A section at right angles to the surface, exhibiting the radial fasciculi of the peripheral system, with the ternate apices of the spicula directly beneath the dermal membrane. × 50 linear. Page 174.

356. ALCYONCELLUM ASPERGILLUM, *Quoy et Gaimard* (Euplectella—*Owen*). A portion of the surface of the sponge, with its great inhalent areas; *a*, the primary longitudinal fasciculi; *b*, the secondary or transverse fasciculi. × 7 linear. Page 177.

357. The oscular area of *A. aspergillum*, with a marginal boundary, and the congregated oscula within, natural size. Page 177.

FIG.

358. POLYMASTIA ROBUSTA, *Bowerbank*. A view of a small portion of the side of one of the large cloacæ, exhibiting the structure and mode of disposition of the longitudinal skeleton fasciculi. × 25 linear. Page 178.

359. HALYPHYSEMA TUMANOWICZII, *Bowerbank*. A complete sponge, based on the stem of a Zoophyte, exhibiting the irregular longitudinal disposition of the skeleton spicula. × 175 linear. Page 179.

360. CIOCALYPTA PENICILLUS, *Bowerbank*. Representing a longitudinal section through the central axis of one of the elongate cloacal portions of the sponge, exhibiting the central column with the small cylindrical pedicels or short fasciculi of closely packed spicula, each terminating at the inner surface of the dermis of the sponge, natural size. Page 181.

361. A section of the specimen represented by Fig. 360, at about the middle of the cloacal column, exhibiting the mode of the radiation of the distal ends of the small pedicels on the inner surface of the dermis. × 25 linear. Page 131.

362. TETHEA CRANIUM, *Lamarck*. A portion of a thin section at right angles to the surface, exhibiting the upper portion of the radiating fasciculi; their terminations being projected beyond the dermal surface of the sponge. × 50 linear.—*a*, porrecto-ternate external defensive spicula; *b*, the mode in which they are supported by buttresses of spicula beneath the surface of the sponge; *c*, the recurvo-ternate spicula. Pages 25, 124 and 183.

363. HALICNEMIA PATERA. A portion of a section at right angles to the surface, exhibiting the mode of disposition of the spicula of the skeleton. × 25 linear. Page 184.

FIG.

364. A portion of the section represented by Fig. 363, taken at *a*, × 108 linear. Pages 184 and 200.

365. DICTYOCYLINDRUS RUGOSUS, *Bowerbank*. Represents a longitudinal section of half of a small branch, exhibiting a portion of the axial column *a*, and the peripheral system arranged in fasciculi, radiating from it. × 50 linear. Pages 24 and 186.

366. A longitudinal section through the axial column of *Dictyocylindrus ramosus*, showing the elongo-reticulate structure of the skeleton of the sponge. × 50 linear. Page 186.

367. PHAKELLIA VENTILABRUM, *Bowerbank*. A longitudinal section of half of one of the primary radial lines of skeleton structure, exhibiting the slender secondary radiation of the skeleton. × 50 linear; *a*, part of the axial column. Page 187.

368. MICROCIONA ATRASANGUINEA, *Bowerbank*. A single mature pedestal of the skeleton, showing its structure and the proportions and positions of the external defensive spicula. × 175 linear. Pages 26 and 188.

369. A section at right angles to the surface of *Microciona astrasanguinea* exhibiting the mode of the disposition of the columns of the skeleton and the dermal surface at *a*. × 108 linear. Pages 26 and 188.

370. HYMERAPHIA STELLIFERA, *Bowerbank*. A section at right angles to the basal membrane, showing the large bulbous skeleton spicula *in situ*, their apices forming the external defences; *a*, the stelliferous internal defensive spicula elevated by a grain of sand beneath the basal membrane. × 108 linear. Fig. 34, Plate I, represents one of this form of spiculum. × 260 linear. Pages 27, 32, 125 and 189.

FIG.

371. Hymedesmia zetlandica, *Bowerbank*. Exhibiting the disjoined fasciculi of the skeleton *in situ*. × 108 linear. See also Fig. 296, Plate XVIII, Page 190.

Sub-Order 2.

372. Hymeniacidon caruncula. Exhibiting the dispersed condition of the skeleton spicula on the interstitial membranes of the sponges. × 108. Page 192.

Sub-Order 3.

373. Halichondria incrustans. Exhibiting a better type of the skeleton structure of the genus than *Halichondria panicea*. × 50 linear. See also Figs. 300, 303, Plate XIX, for *Halichondria panicea*. Page 195.

374. Hyalonema mirabilis, *Gray*. The figure represents a portion of the spiral fasciculus of single, elongated and very large spicula, forming the axial skeleton of a columnar cloacal system; surrounded by a portion of its coriaceous envelop, exhibiting numerous oscula on its surface; natural size. Copied from the figure in the 'Proceedings of the Zoological Society of London, for 1857.' Page197.

375. A portion of the skeleton of *Hyalonema mirabilis*, Gray, showing the indefinite nature of the separated elongated fasciculi of the skeleton. × 50 linear. Page 197.

376. Isodictya Normani. Exhibiting the regular and nearly rectangular structure of the network of the skeleton of spicula. × 108.

Spongilla. Agrees perfectly in the structure of the skeleton with *Isodictya*, but is distinguished from that genus by the peculiarities of the reproductive organs. Pages 197 and 199.

Sub-Order 4.

Desmacidon.—See Fig. 264, Plate XIII.

Raphyrus.—See Fig. 265, Plate XIII.

Sub-Order 5.

Fig.

377. Diplodemia vesicula. A small portion of its compound reticulate skeleton, exhibiting the intermixture of the spiculo-reticulate skeleton with the hetrospiculate fibrous one. × 108 linear. See also Fig. 273, Plate XIV, for structure of hetrospiculate fibre. × 175 linear. And Fig. 324, Plate XXIII, for the ovaria. × 83 linear. Page 202.

For 378 see page 289.

Sub-Order 6.

Dactylocalyx.—See Figs. 274, 275 and 276, Plate XV, for skeleton fibre, and Figs. 240 and 241 for structure of the skeleton and gemmules.

Sub-Order 7.

Farrea.—See Fig. 277, Plate XV, for the structure of the fibre and form of the skeleton; and Fig. 311, Plate XXI, for dermal structure.

Order 3.—Keratosa.

Sub-Order. 1

379. Spongia, *Linnæus*.—Showing the irregularity of the disposition of the keratose fibre. × 50 linear. See also Fig. 261, page 13, for the structure of the fibre.

Fig

380. Spongionella pulchella, *Bowerbank.*—Exhibiting the nearly rectangular mode of disposition of the primary and secondary keratose fibres of the skeleton. × 50 linear.

Sub-Order 2.

378. Halispongia, *Blainville.* Showing one of the large primary keratose fibres, containing siliceous spicula, and the irregular system of small aspiculous keratose fibres. × 175 linear.

Sub-Order 3.

—. Chalina, *Grant.* See Figs. 262, 263, Plate XIII.

Sub-Order 4.

—. Verongia, *Bowerbank.*—See Fig. 266, Plate XIII.

Sub-Order 5.

—. Auliskia, *Bowerbank.*—See Fig. 267, Plate XIII, and Fig. 268, Plate XIV.

Sub-Order 6.

381. Stematumenia, *Bowerbank.*—A section at right angles to the surface of a young *Stematumenia* exhibiting the regular semi-areno fibrous skeleton and the fibro-membranous interstitial structure *in situ.* × 175 linear. See also Figs. 256, 257, and 260, Plate XII, and Fig. 269, Plate XIV. Page 211.

Sub-Order 7.

Fig.

381. Dysidea fragilis, *Johnston.*—See Fig. 271 for a portion of the skeleton, and Figs. 270 and 272, Plate XIV, for fibres of the skeleton.

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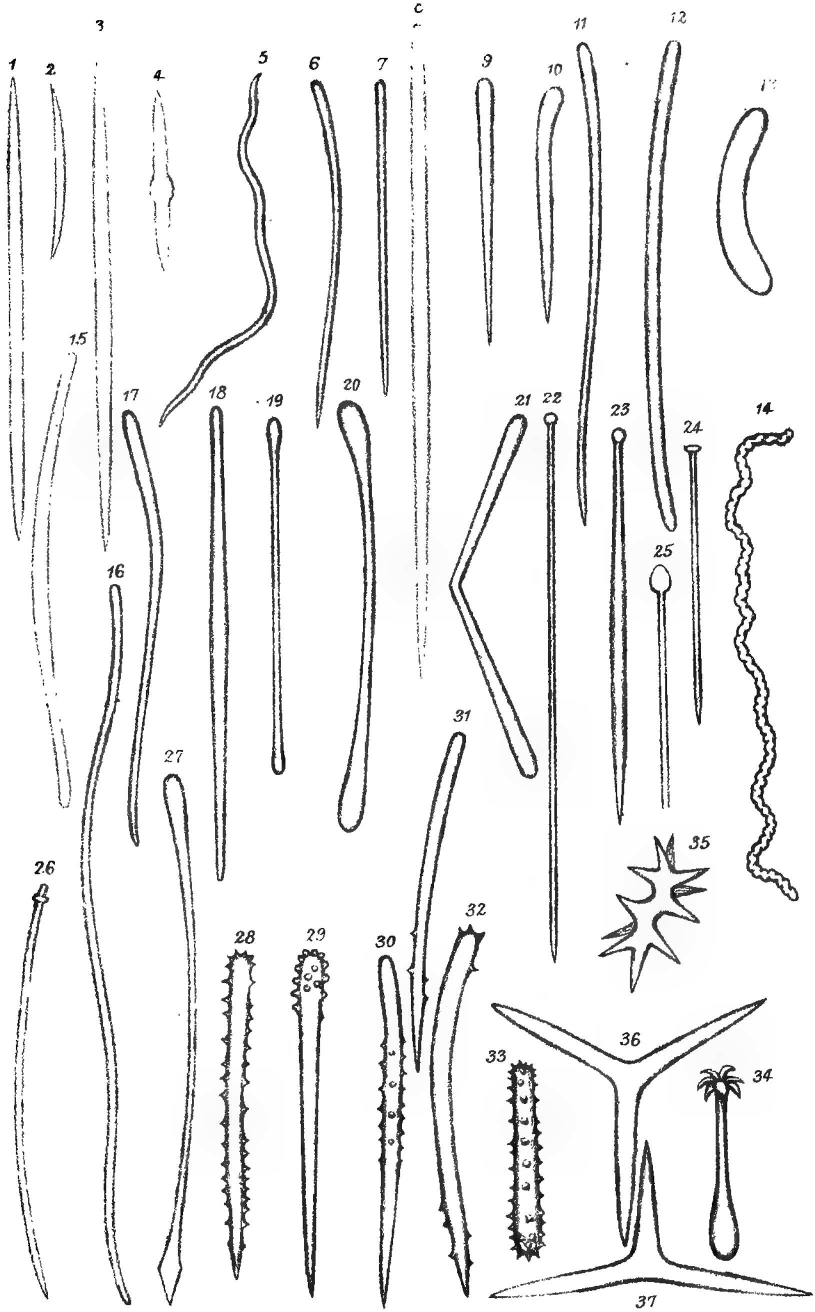
1 — 37.



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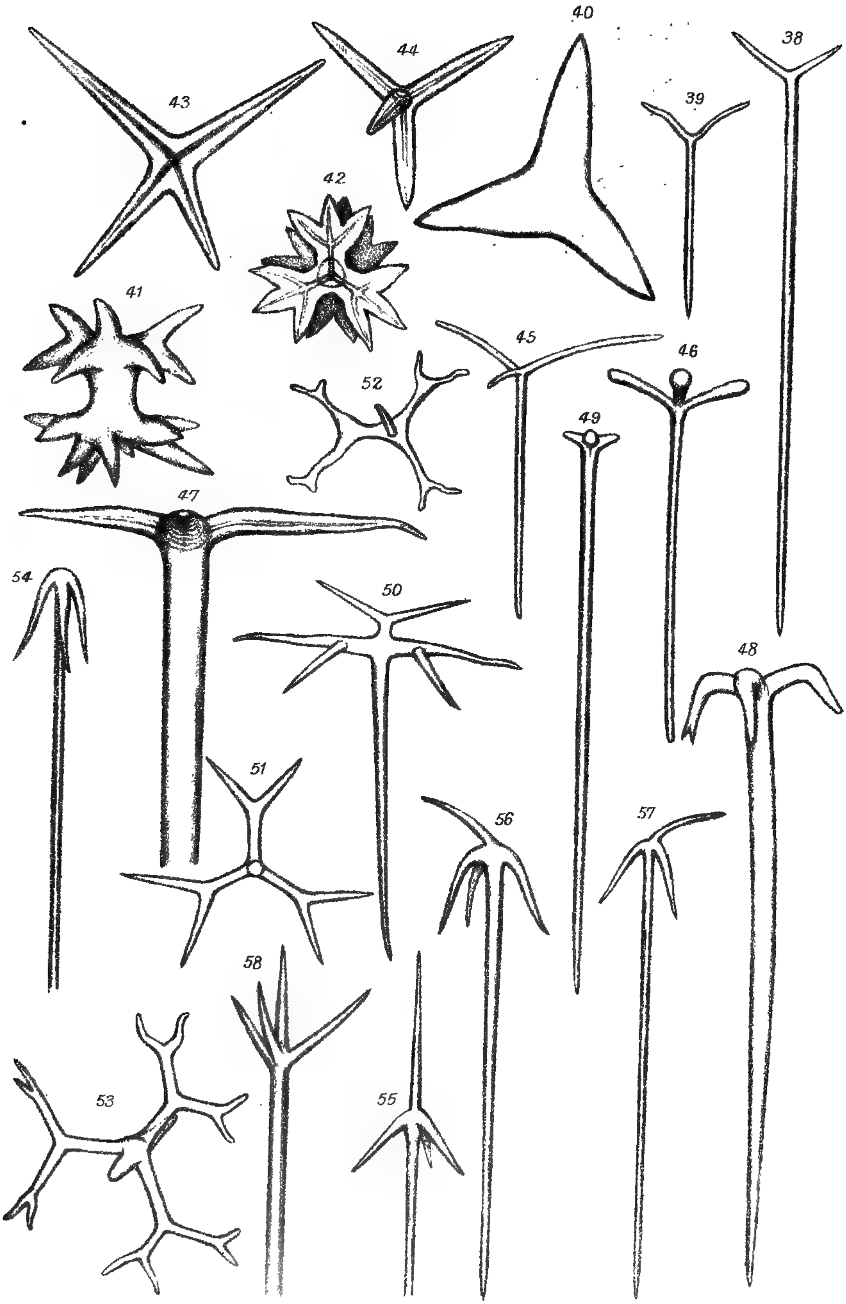

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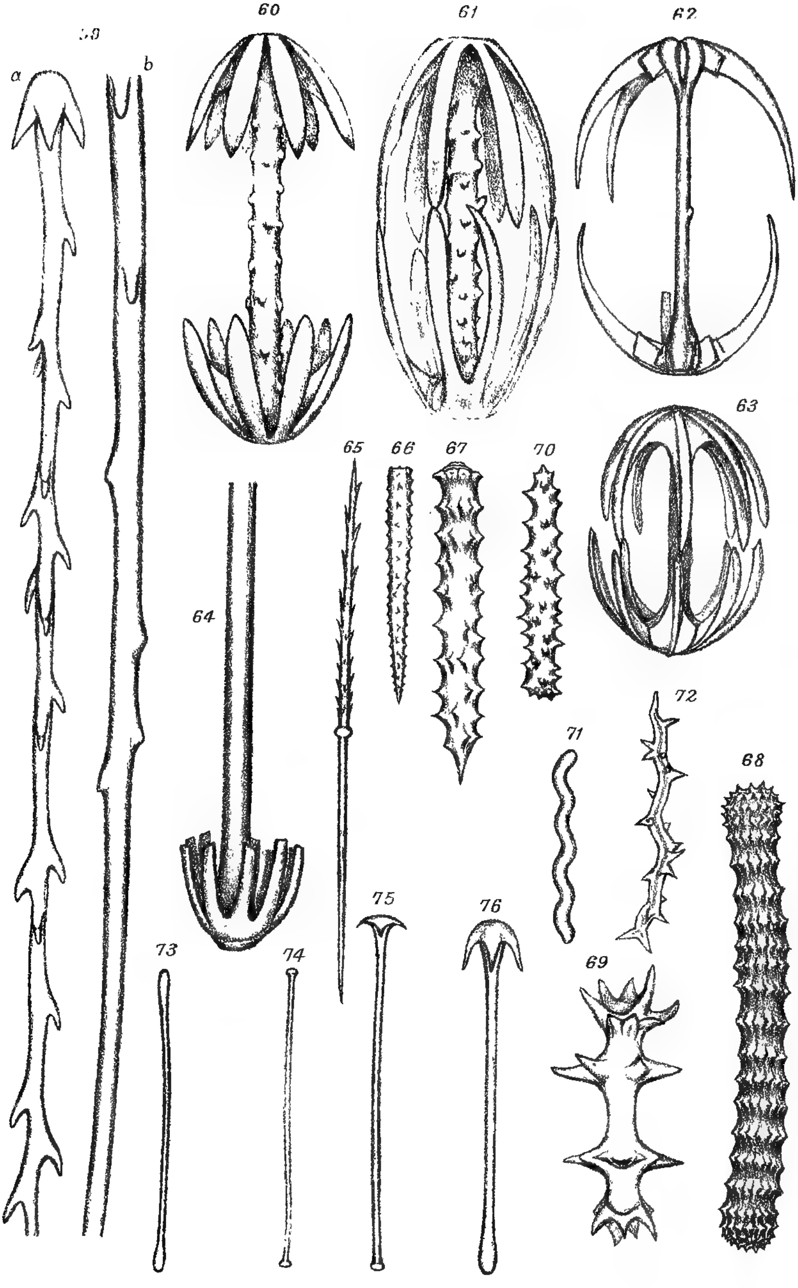
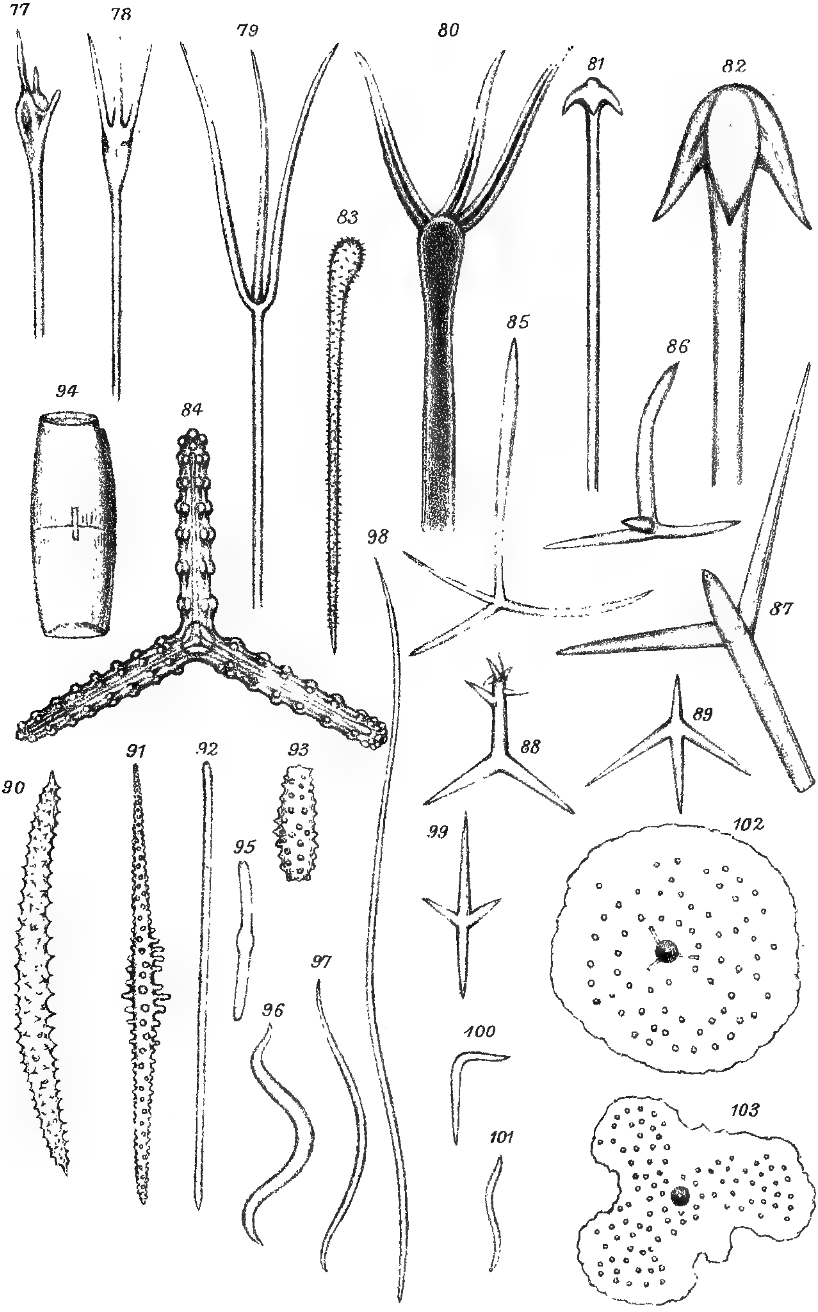
59 — 76



77 — 103.



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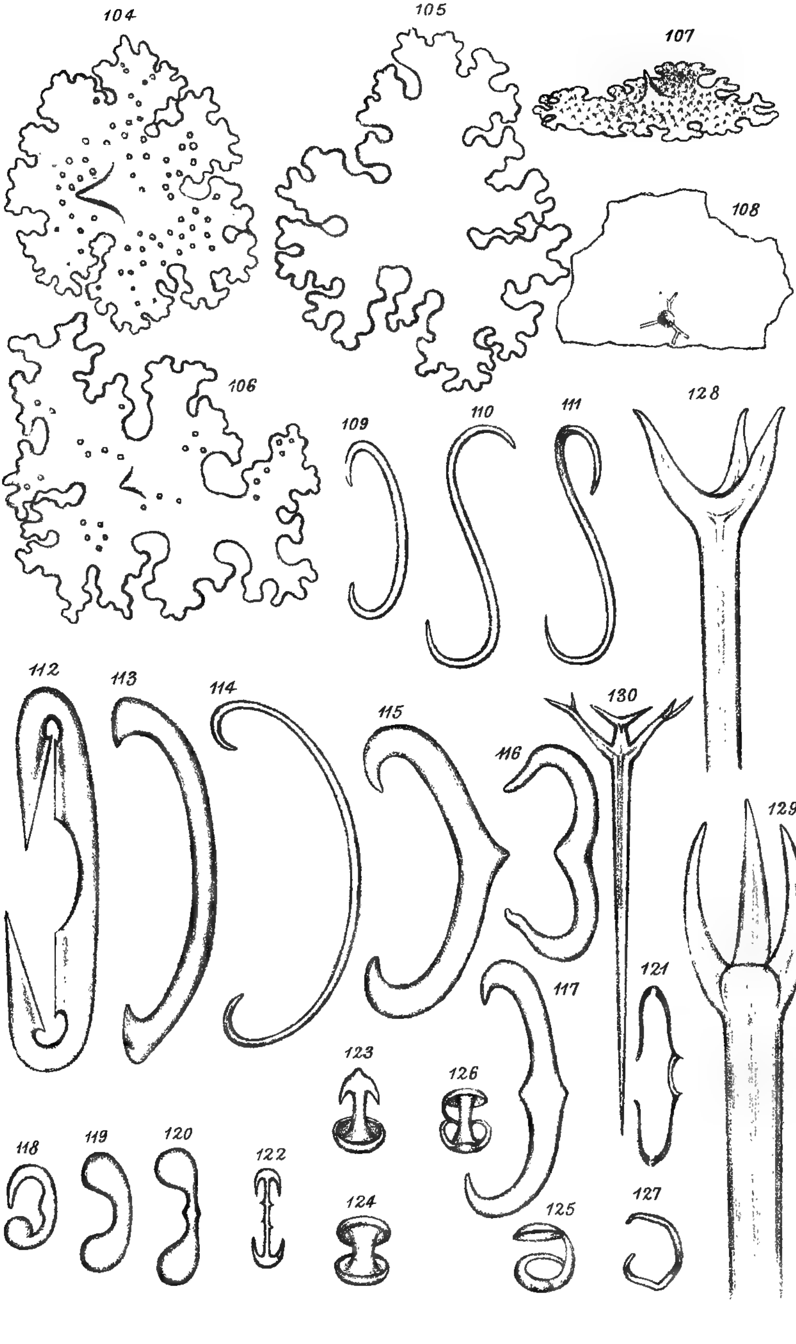
104 — 130.



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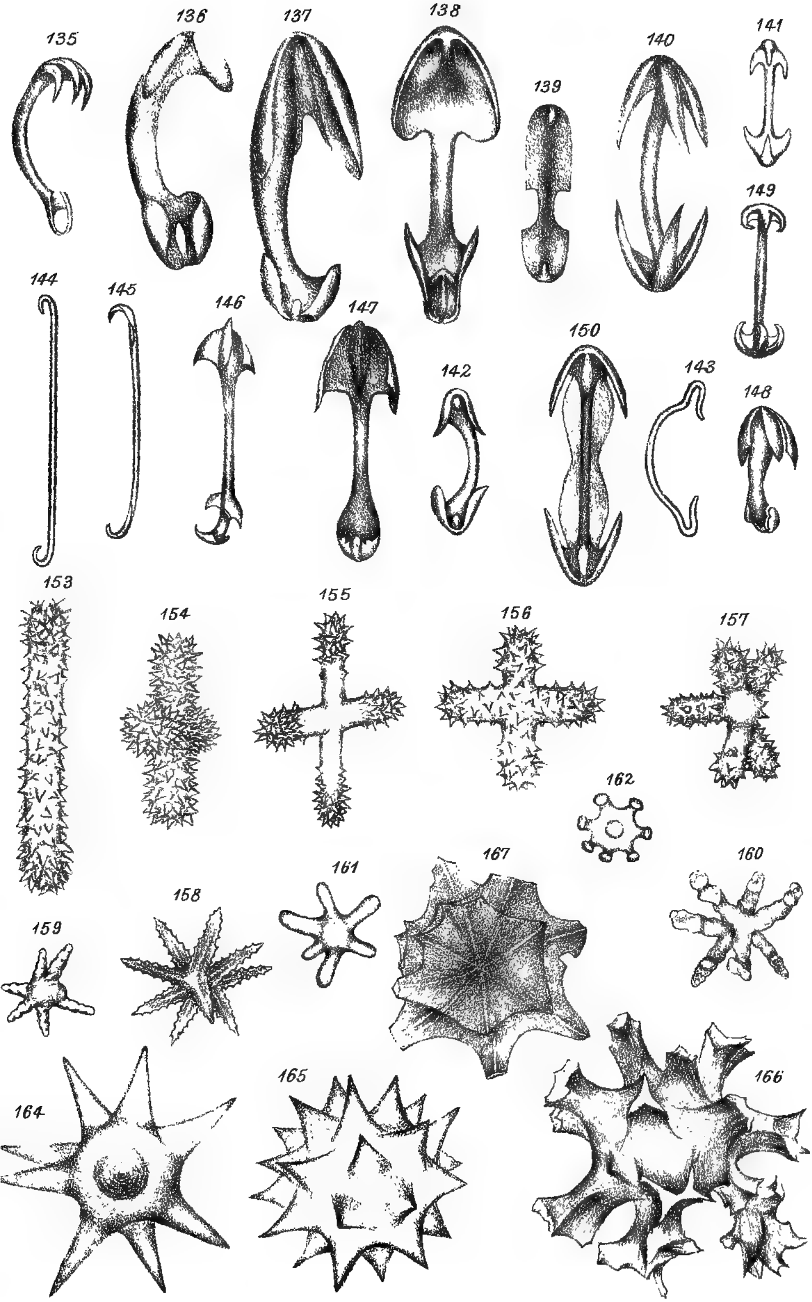
Pl. VI.

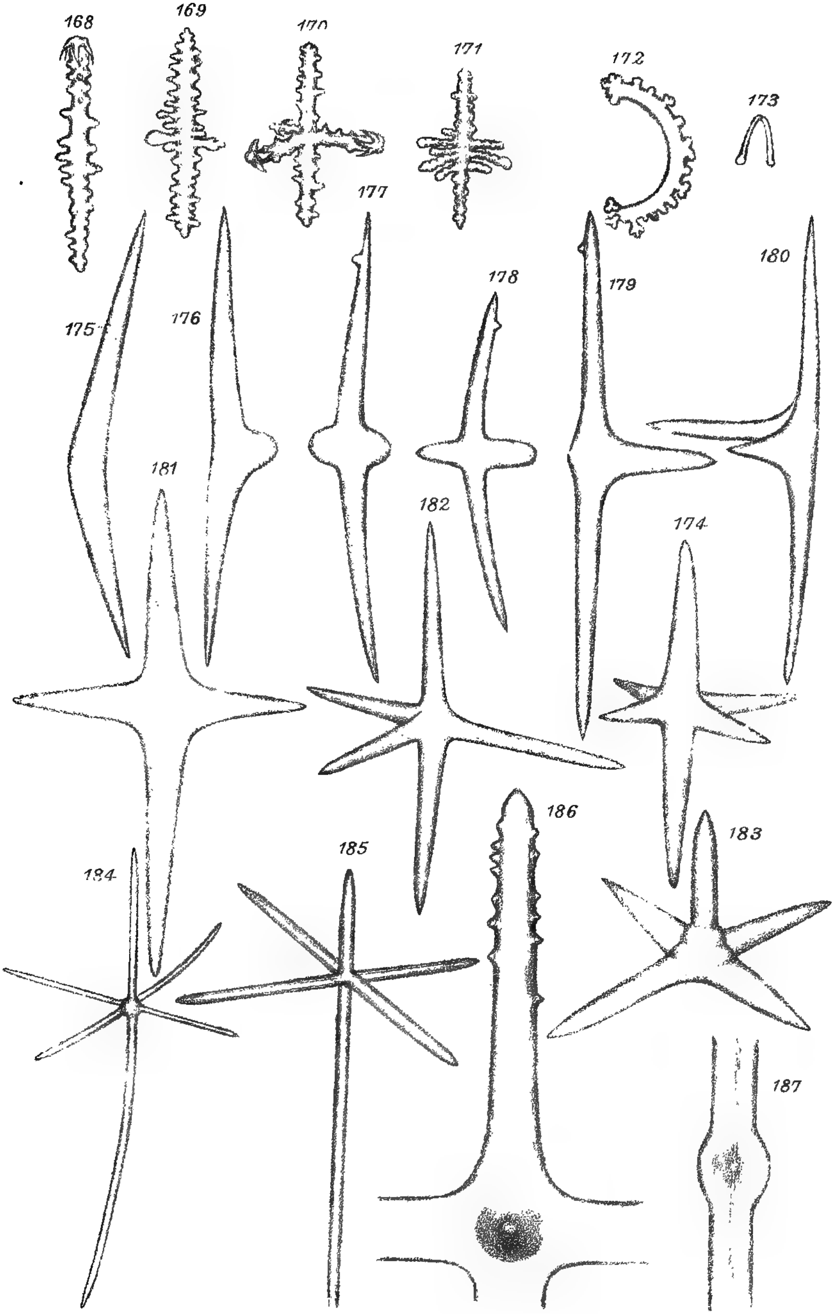
135 — 167.



151 & 152 see Plate 37, & 163 see Plate 10.

W. Lens Aldous del. et lith. W West imp.

168 — 187.



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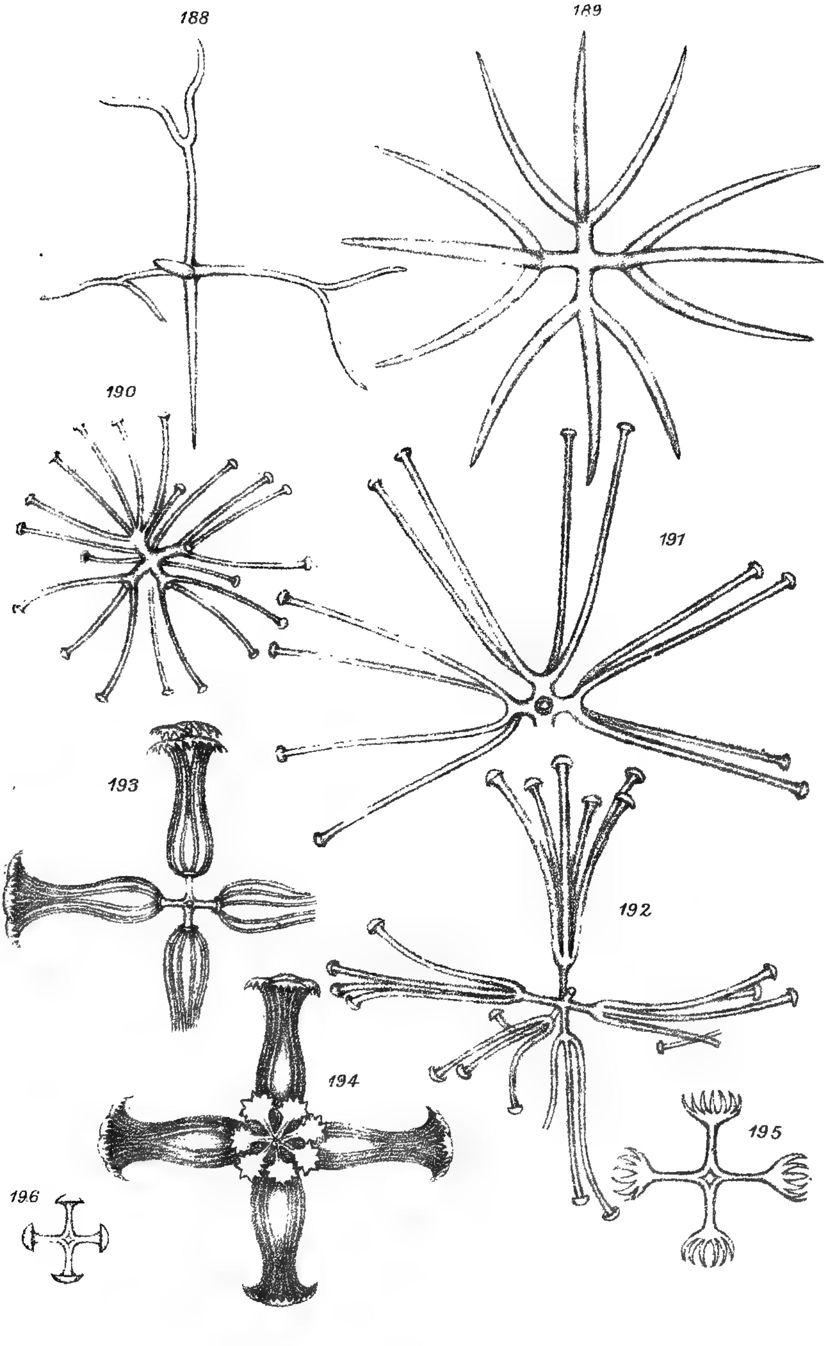
188 — 196

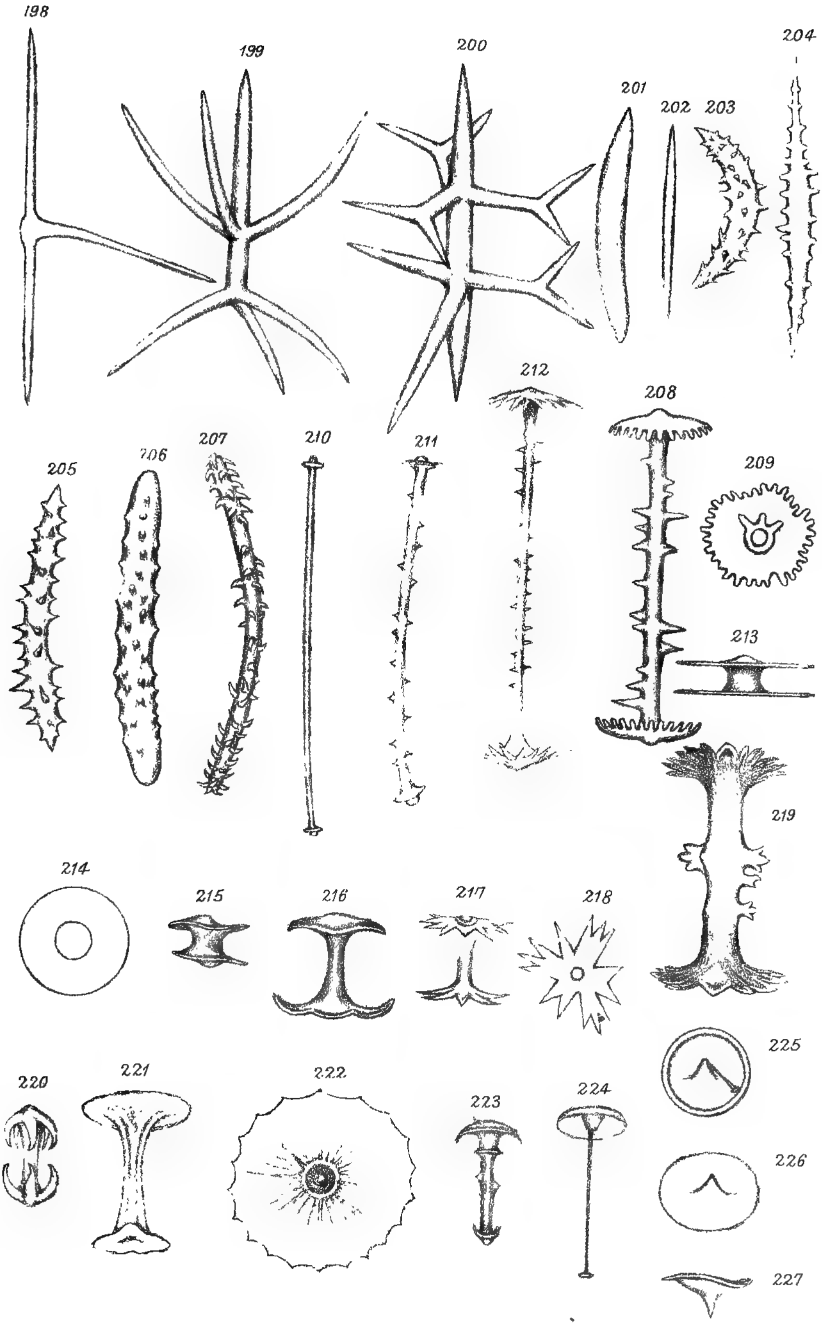


Lens Aldous del. et lith

For 197, see Plate 10.

W West imp

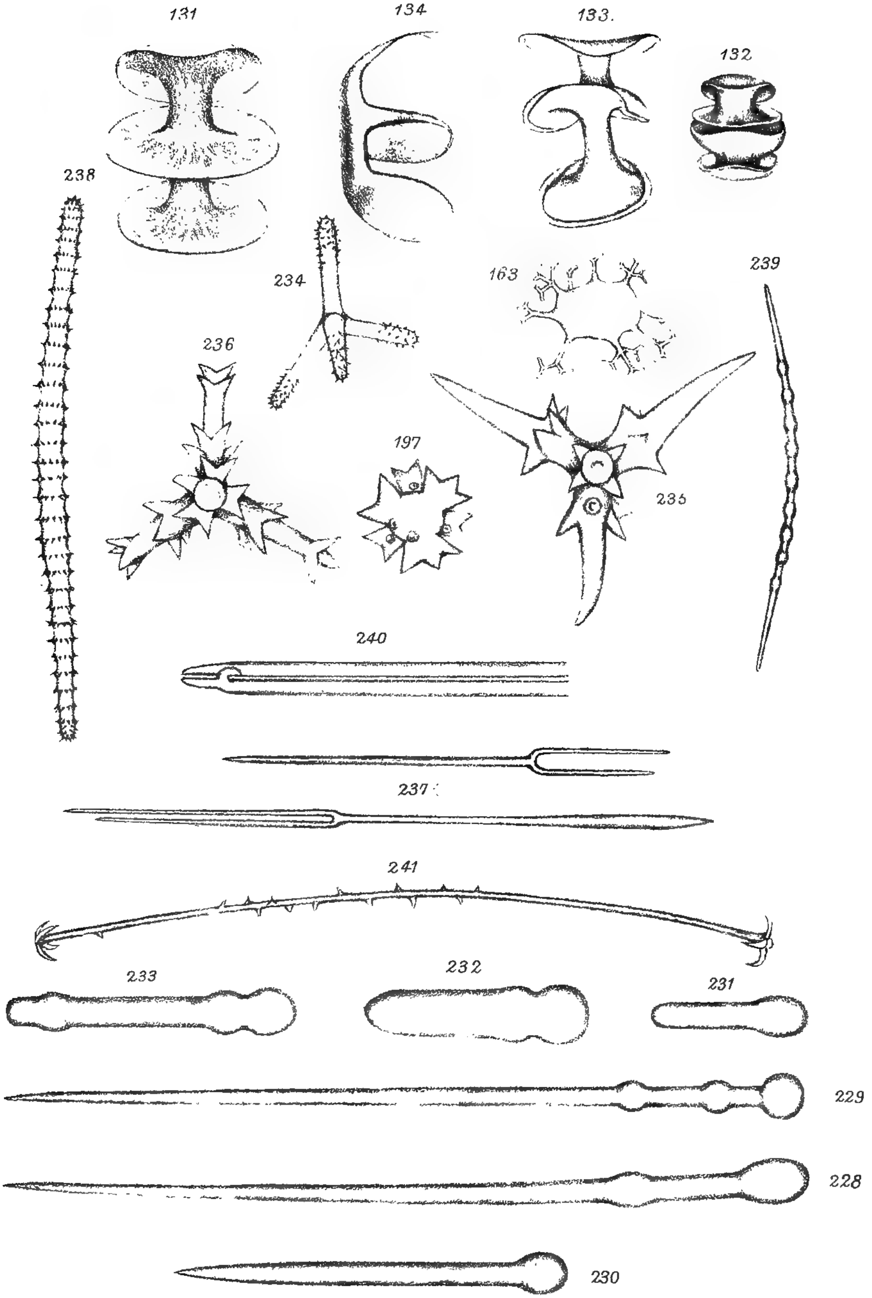
198 — 227



W. Lens Aldous del. et lith

W West imp

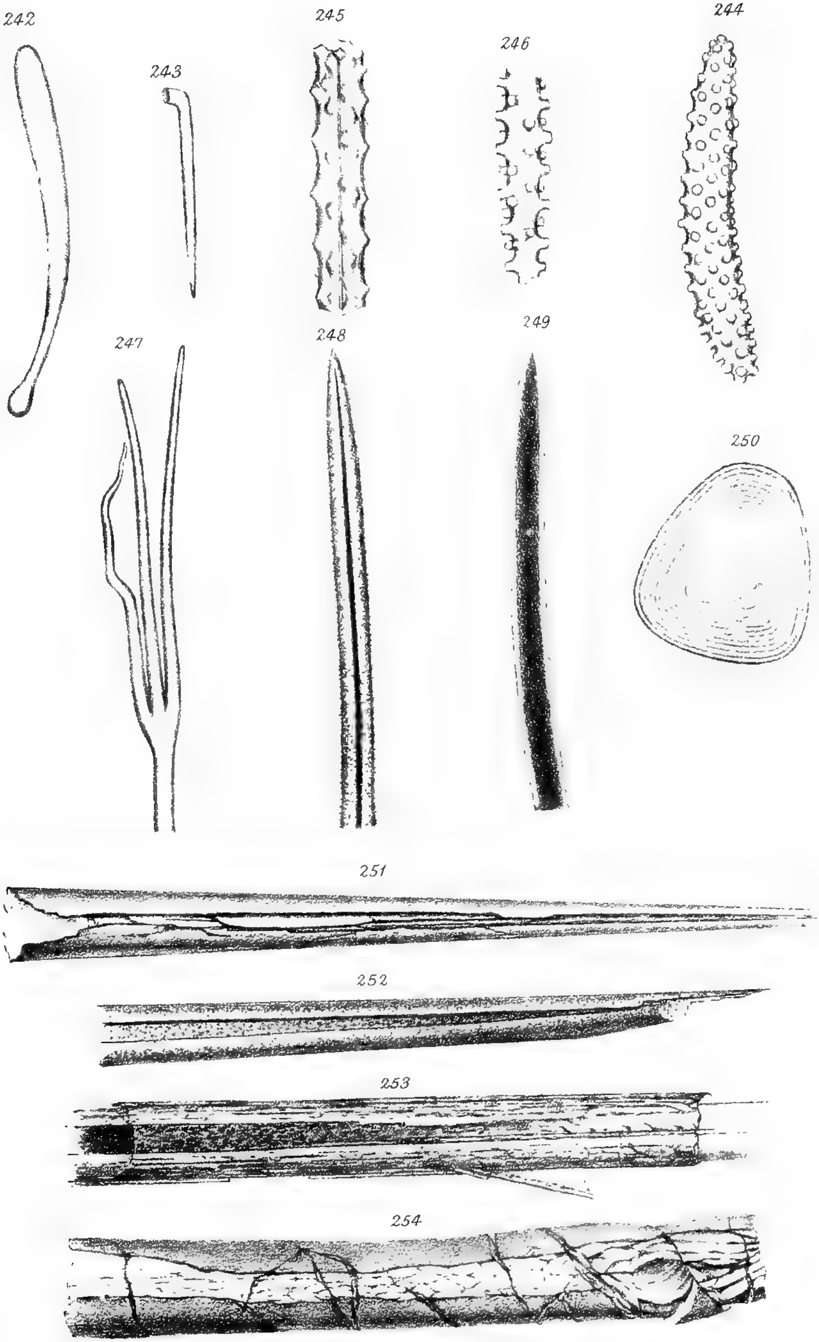
228 — 241



W. Lens Aldous del et lith.

W West imp

242 — 254.

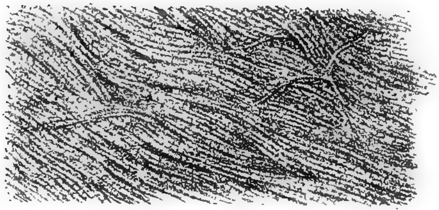


W West imp

W Lens Aldous del et lith

255 — 260

255



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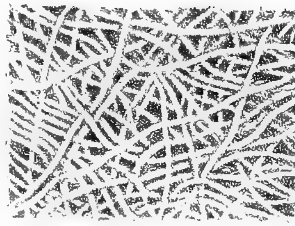

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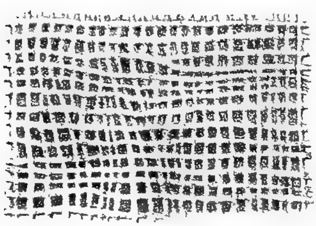

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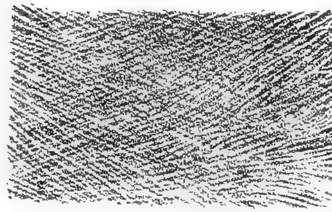

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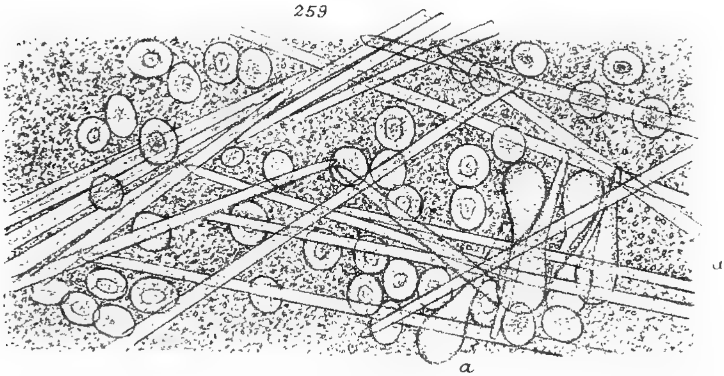

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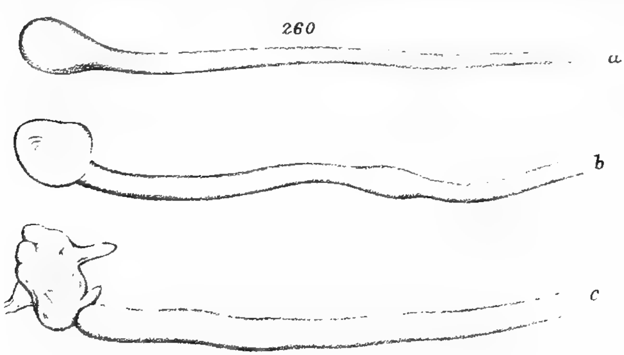
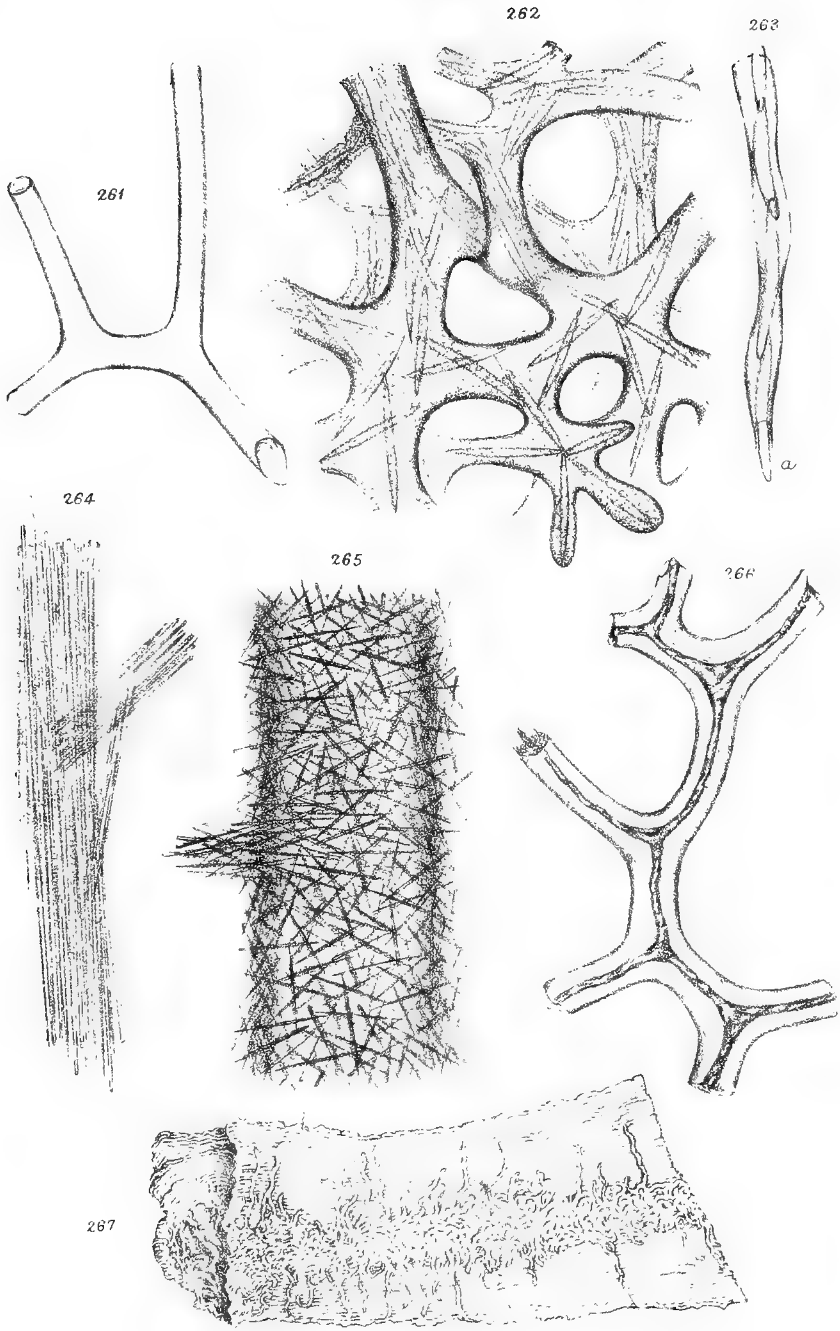


W. Iens Aldous del et lith

W West imp

261 — 267.

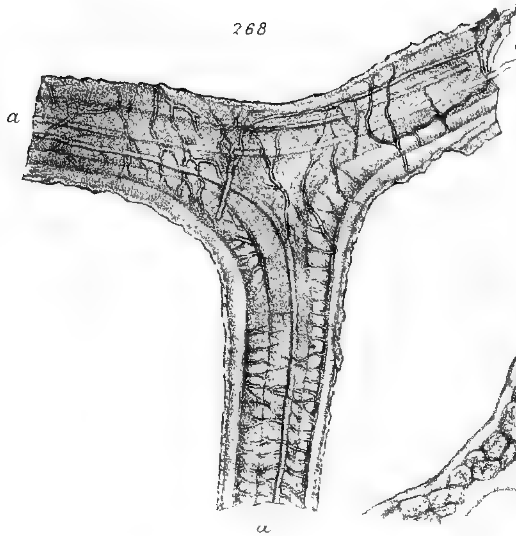


W. Lens Aldous del. et lith.

W. West imp.

268 — 273.

268



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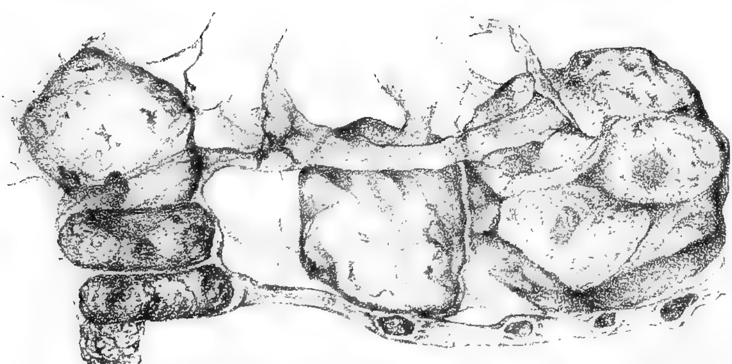
271



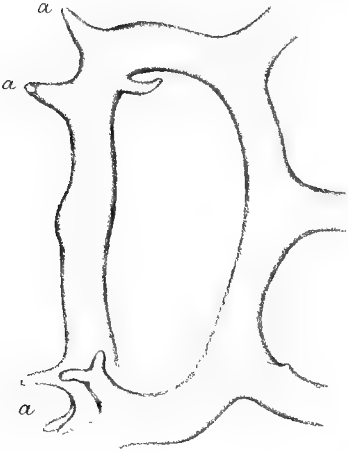
273

272

W Lens Aldous del et lith

W West

274



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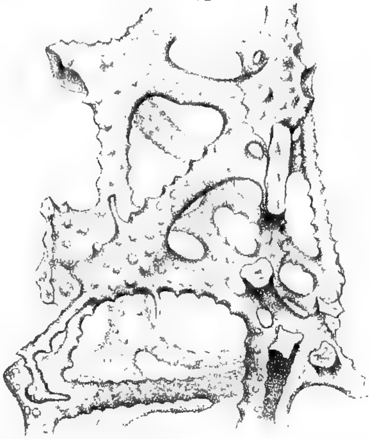

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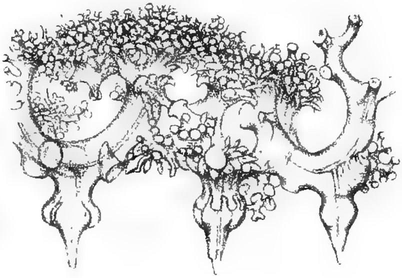

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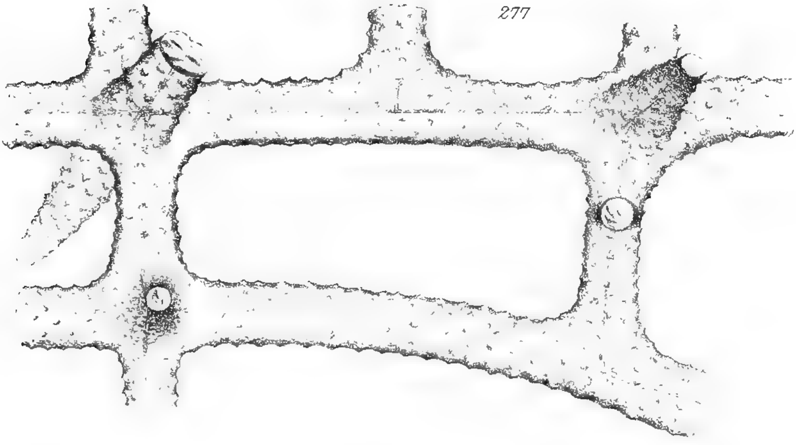


W Lens Aldous del. et lith

W West imp

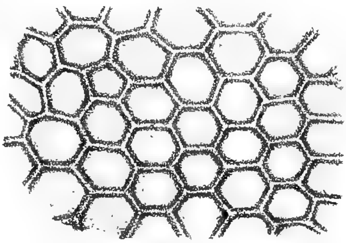
279 — 285

279

280

281

284



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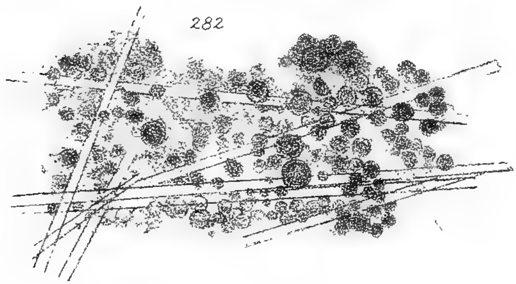

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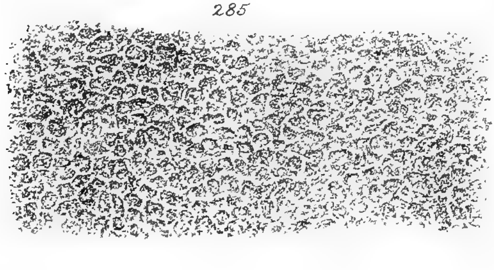
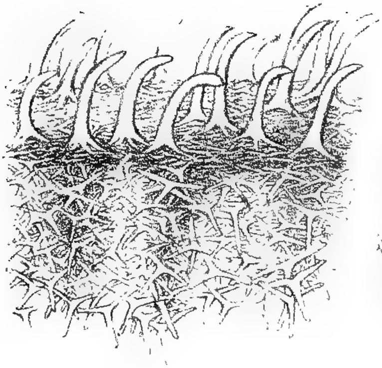


W Jens Alnous del et lith

W West imp

286



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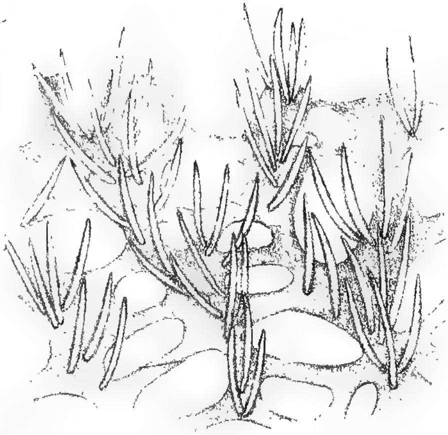

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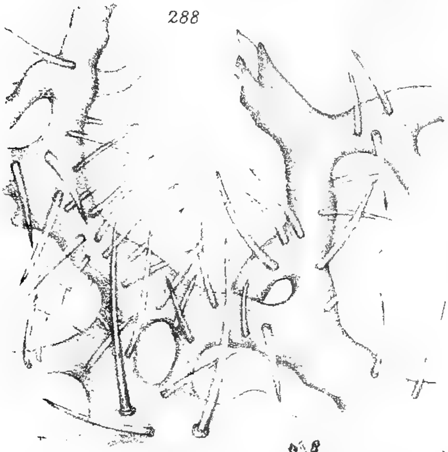

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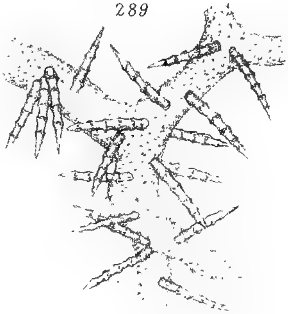

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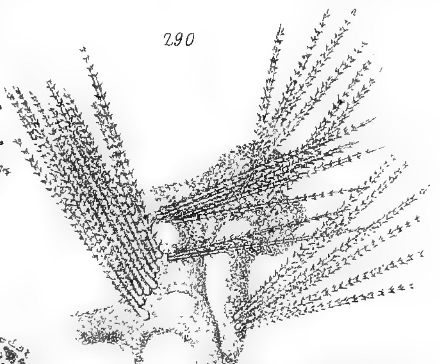


291

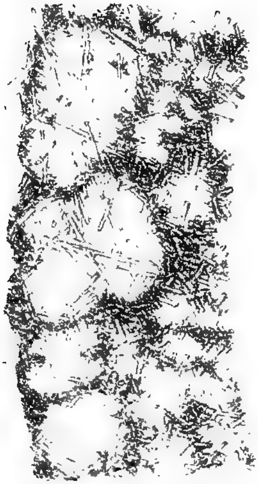
b

a

W Lens Aldous del et lith

W West imp

299



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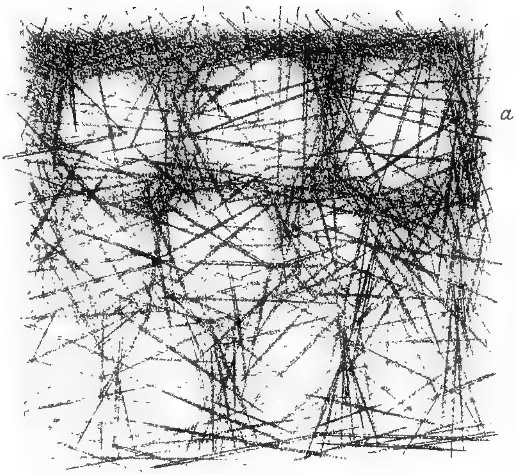

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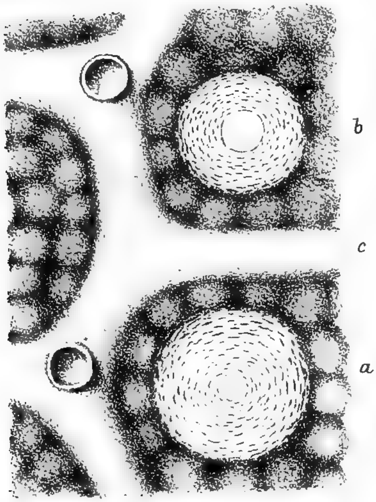

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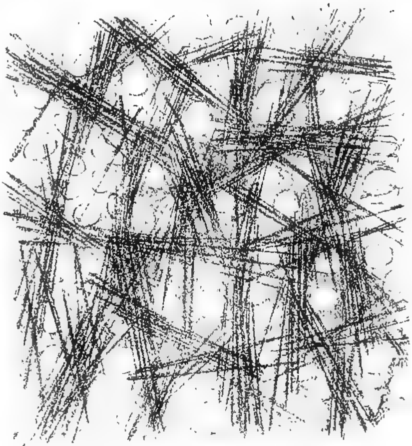

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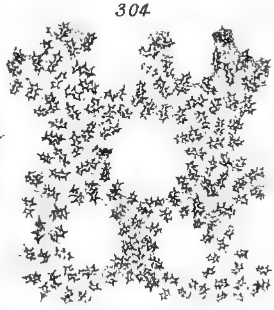

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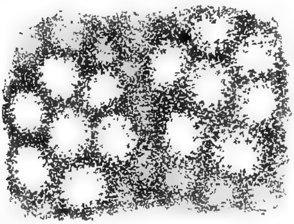

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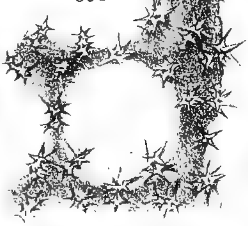
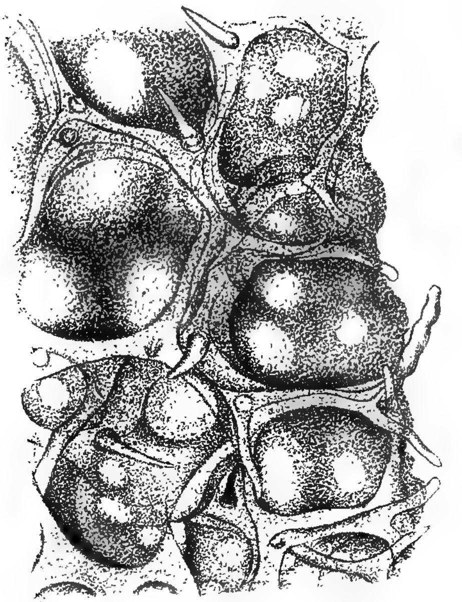


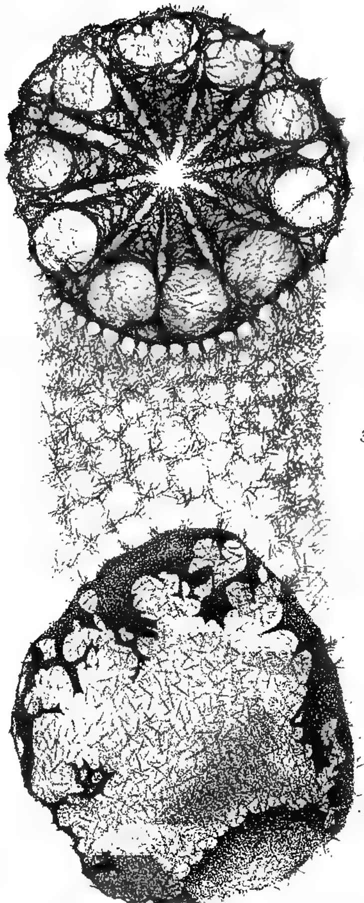
W Lens Aldous del et lith

W West imp

306 — 310.

306



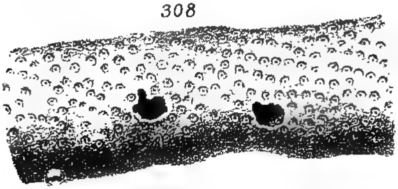


a

307

b

308



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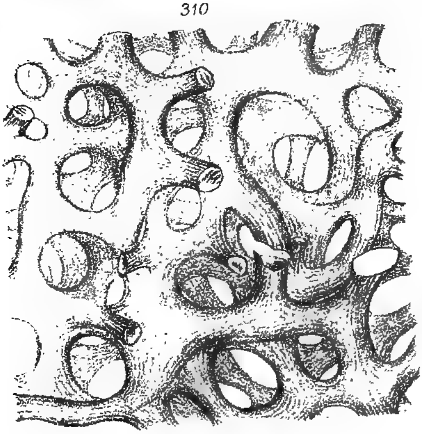

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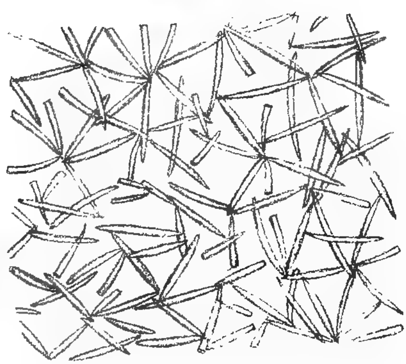
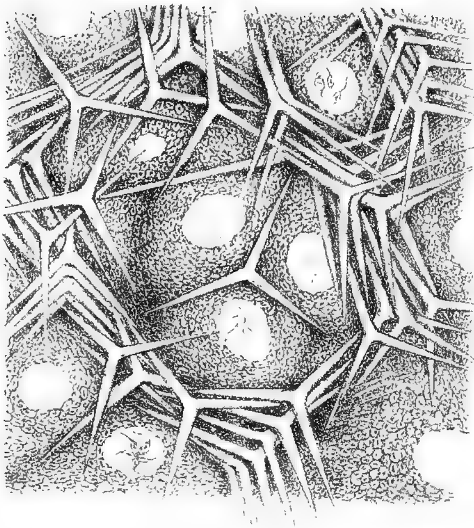


W West imp.

W Lens Aldous del et lith

311 . 314.

313



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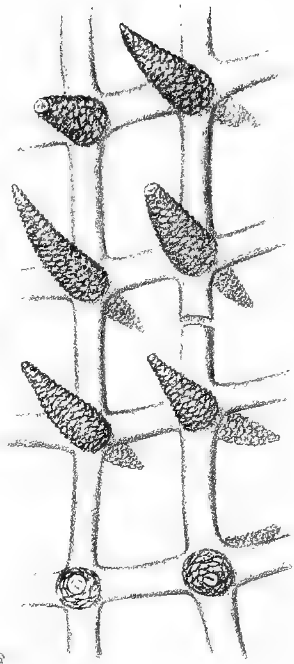

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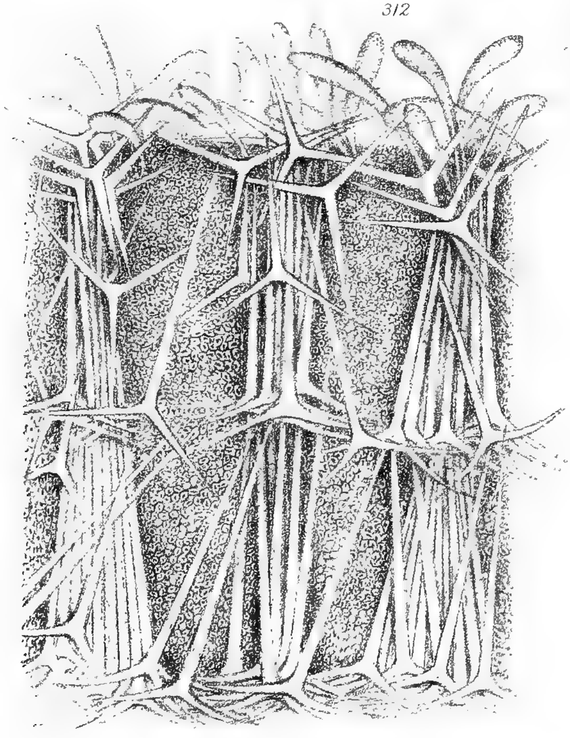


314

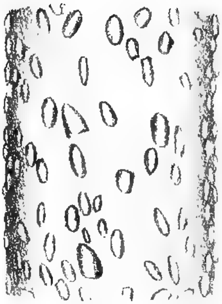
W Lens Aldous del et lith

W West imp

315 ... 321

315

316



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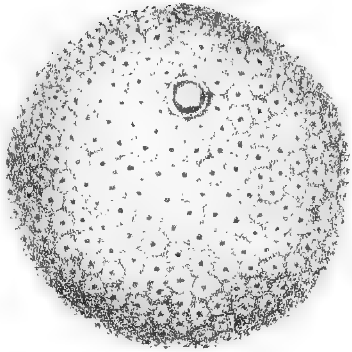

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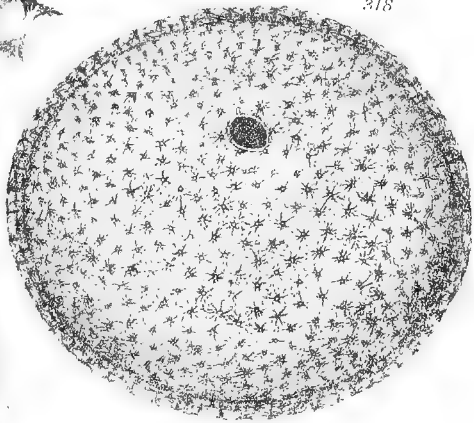

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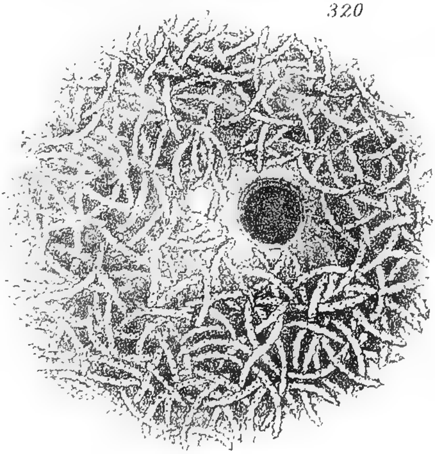

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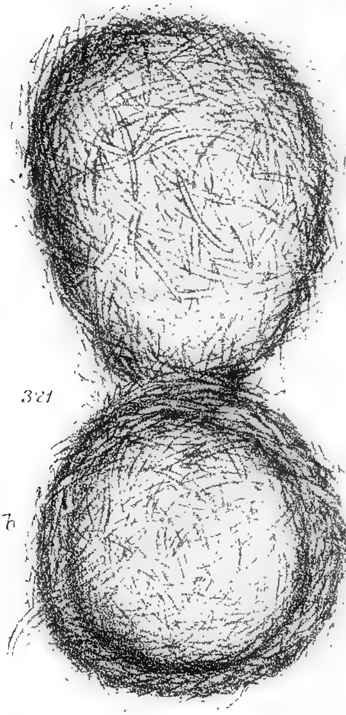
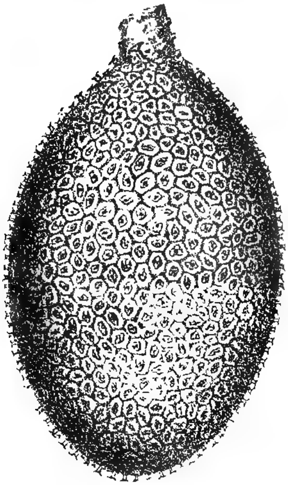


W Lens Aldous del et lith

W W

322 — 328.

323



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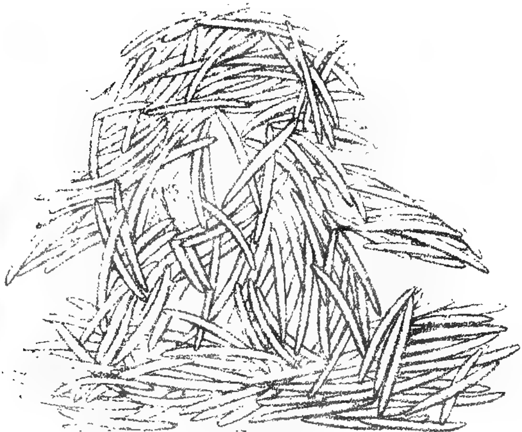
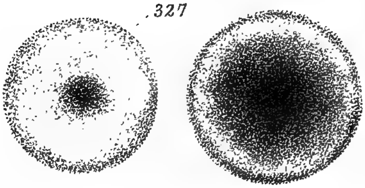


324

327

b



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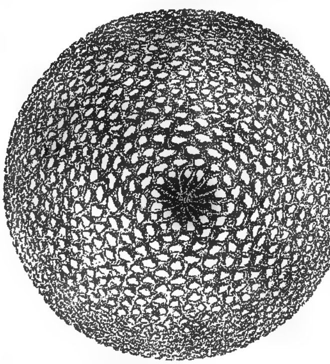
325



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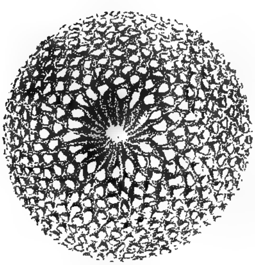

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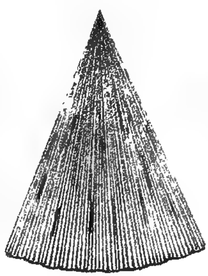
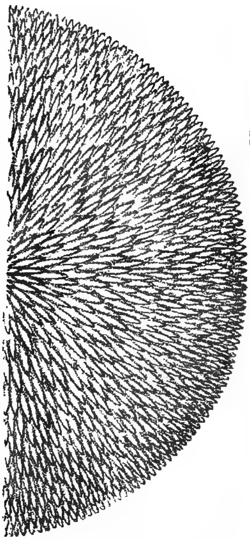


W Lens Aldous del. et lith.

W West imp.

329 — 339.

329



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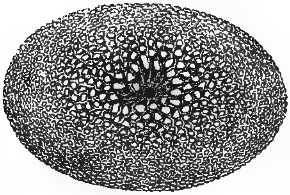

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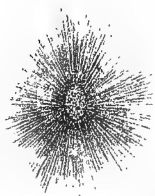

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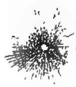

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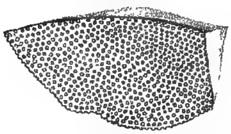

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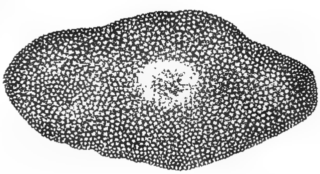

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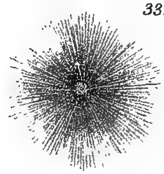

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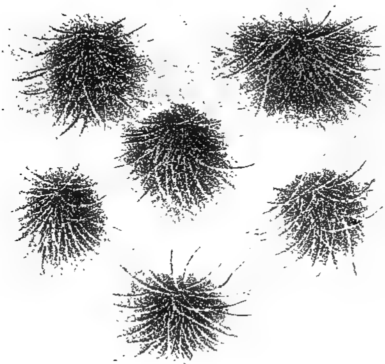

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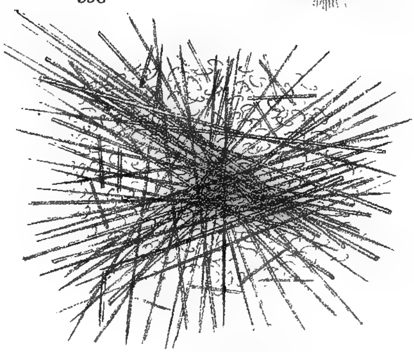

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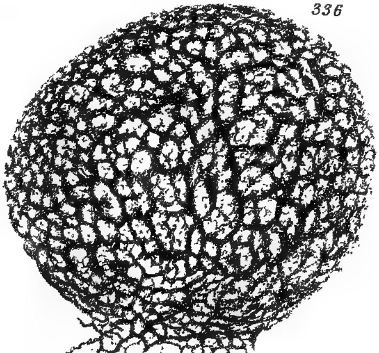

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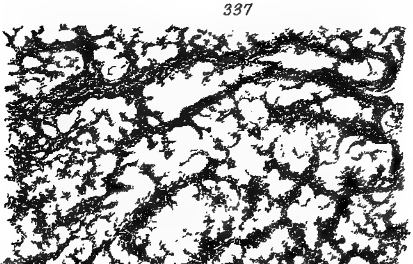
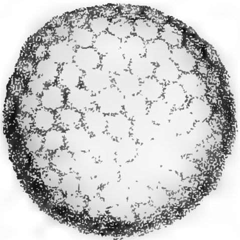


W Lens Aldous del. et lith.

W West imp.

340 — 344.

344



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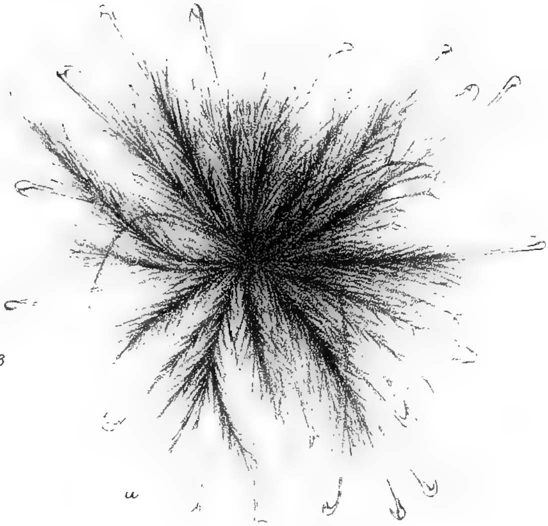

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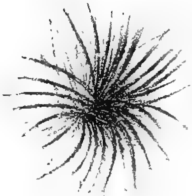
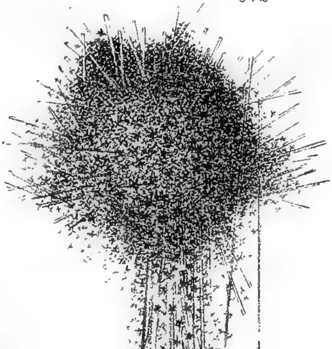


b

342



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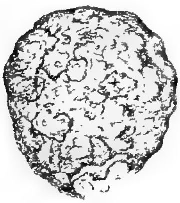

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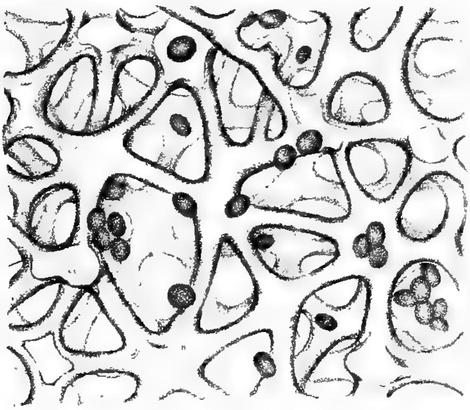
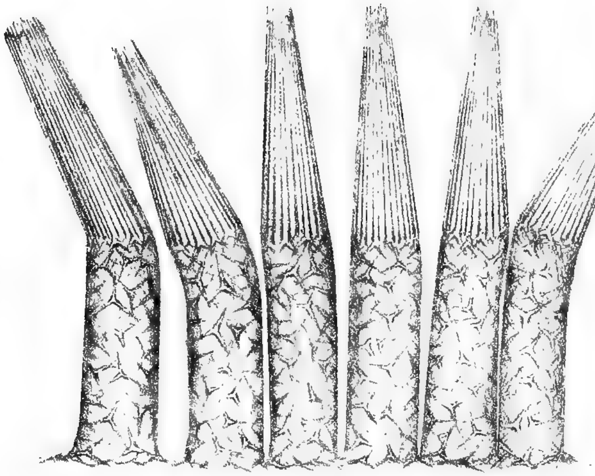


W Lens Aldous del. et lith.

W West imp.

345 — 350

345



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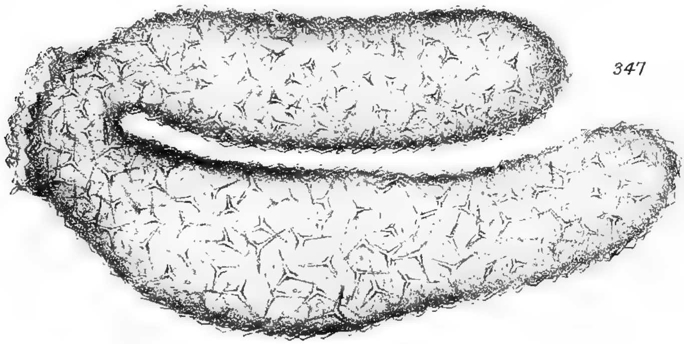

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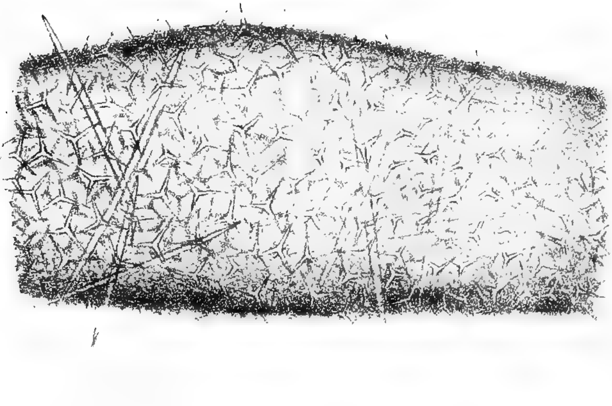
348

349



350

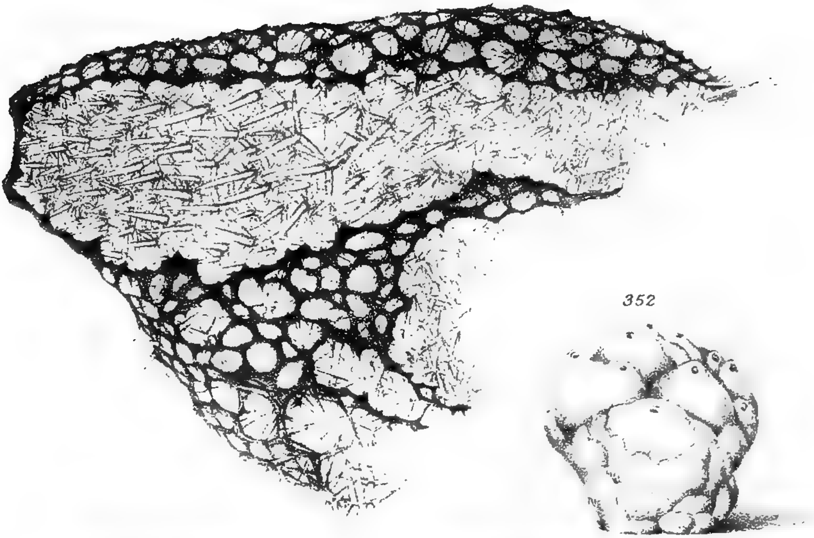
W. Lens Aldous del. et lith

W West imp

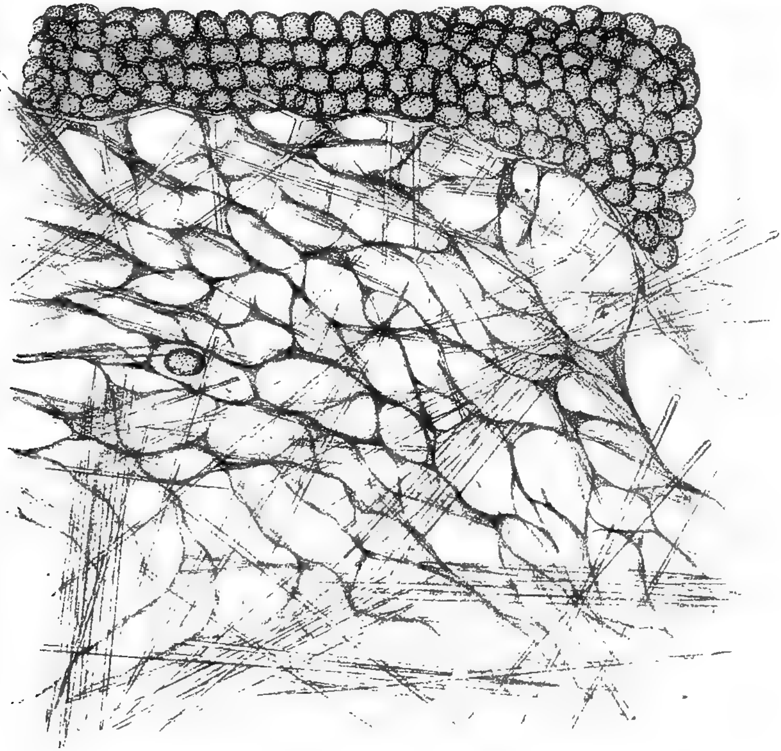
351 — 353

351

352



353

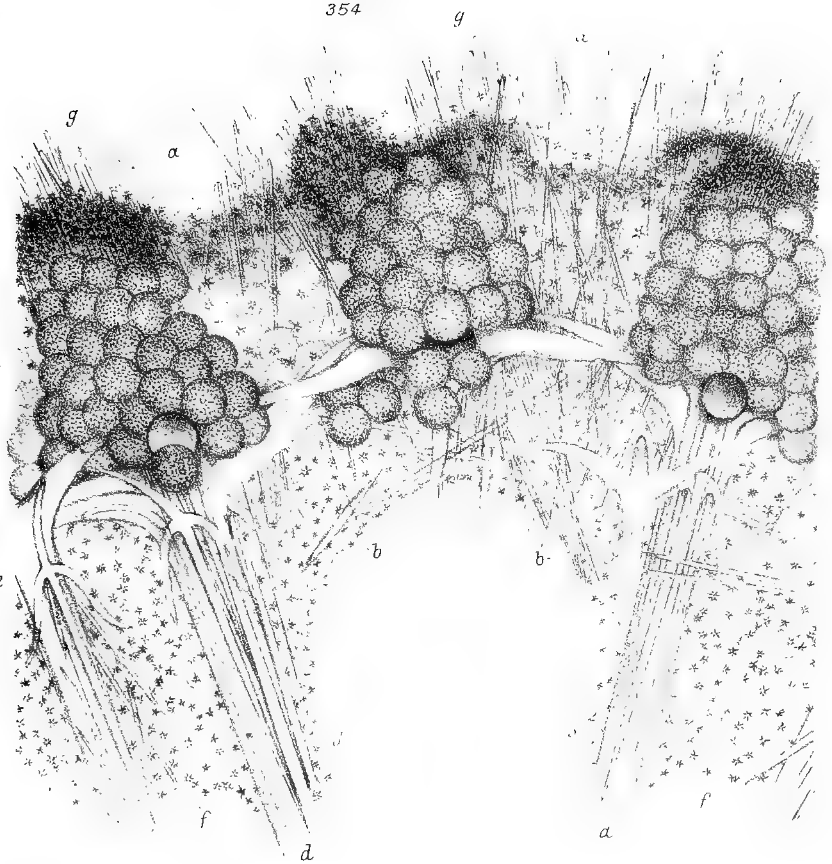


W. Lens Aldous del et lith

W West imp

354 — 355

354



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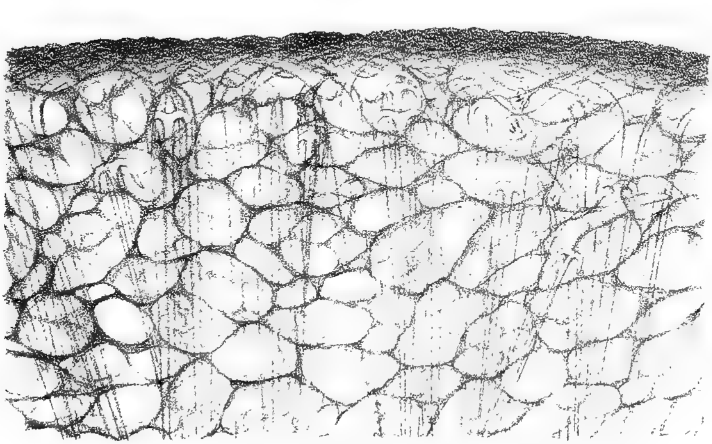
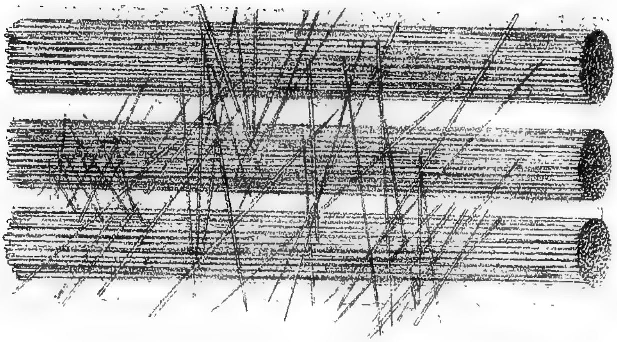


W Lens Aldous del et lith

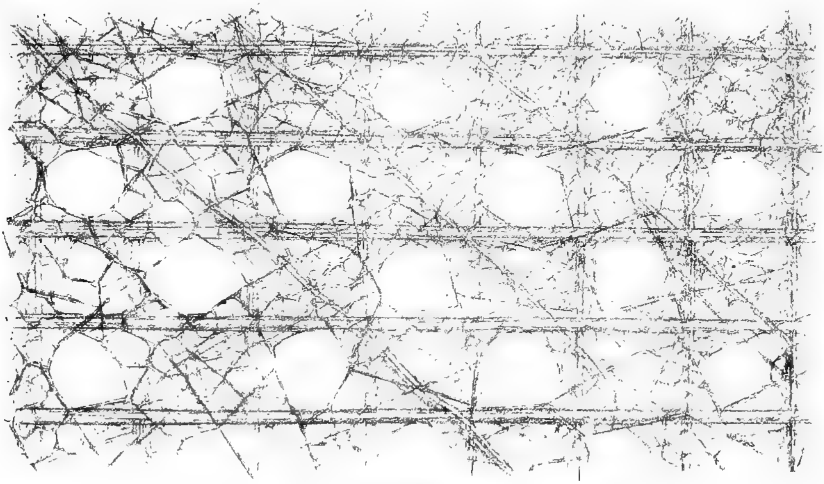
W West imp

356 _ 358

358



356 b



a

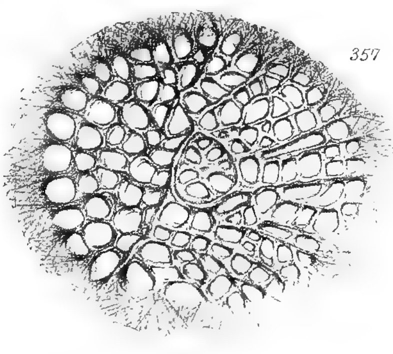
a

a

a

b b

357



W. Lens Aldous del et lith

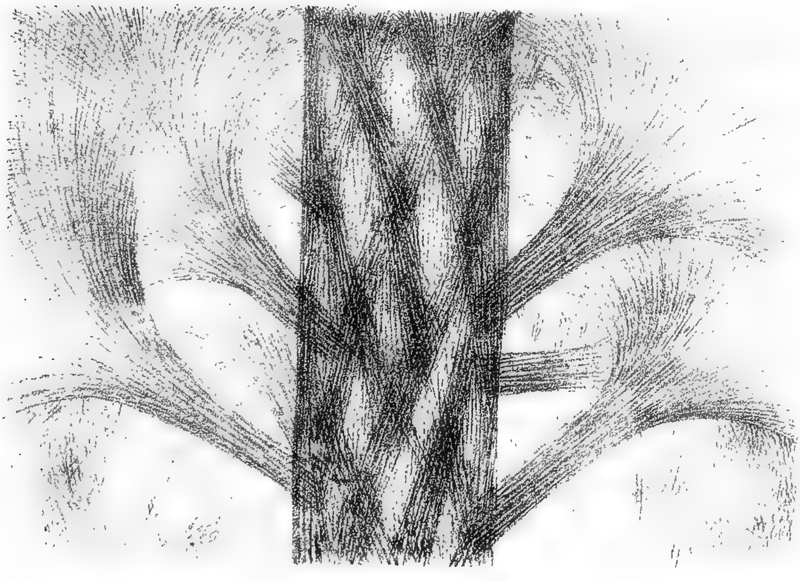
W West imp

359 — 361.

360

359

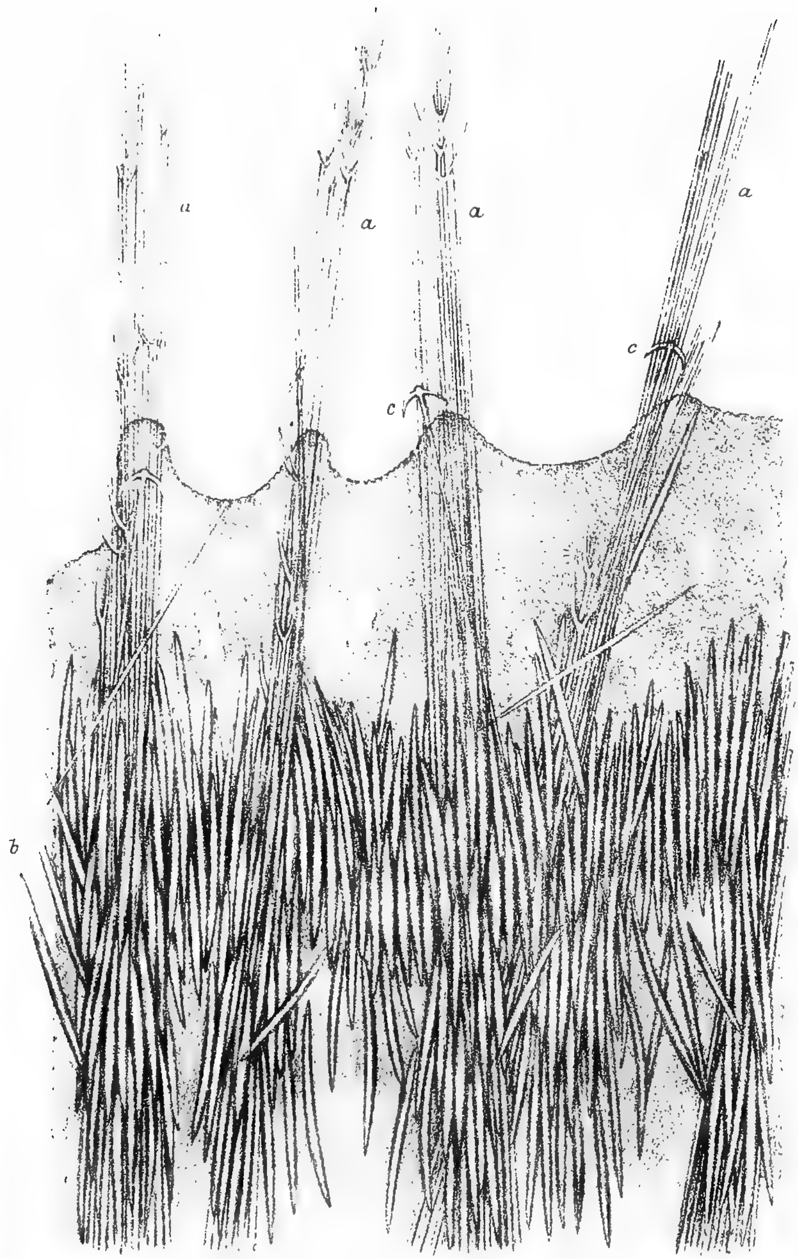
361



W. Lens Aldous del. et lith.

W West imp.

362

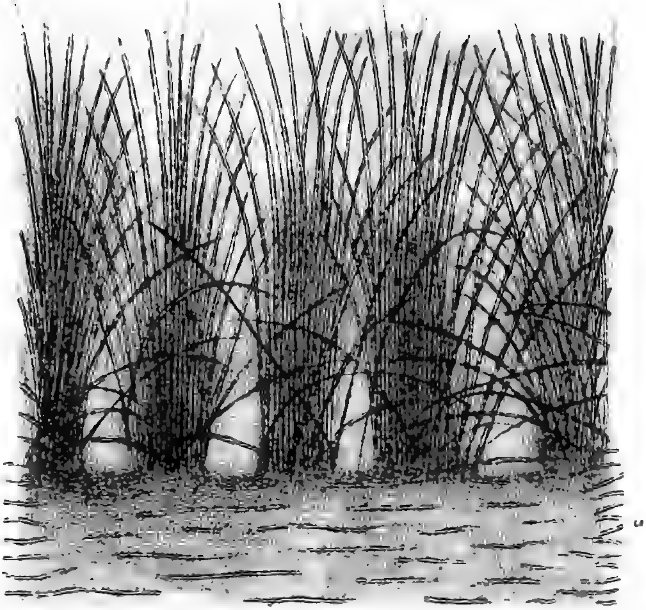


W Lens Aldous del et lith

W West imp

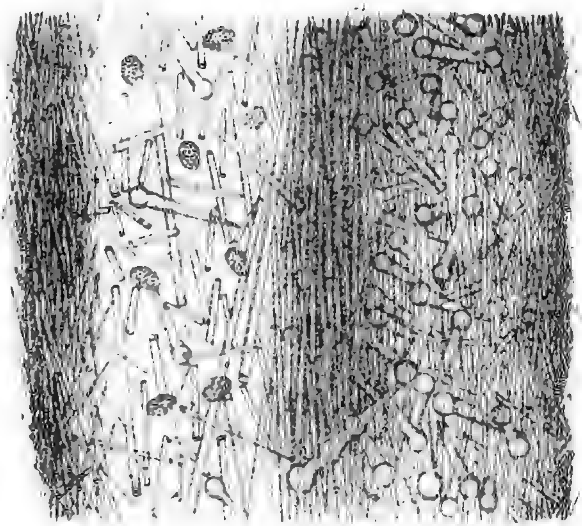
363 — 365

365



363

364

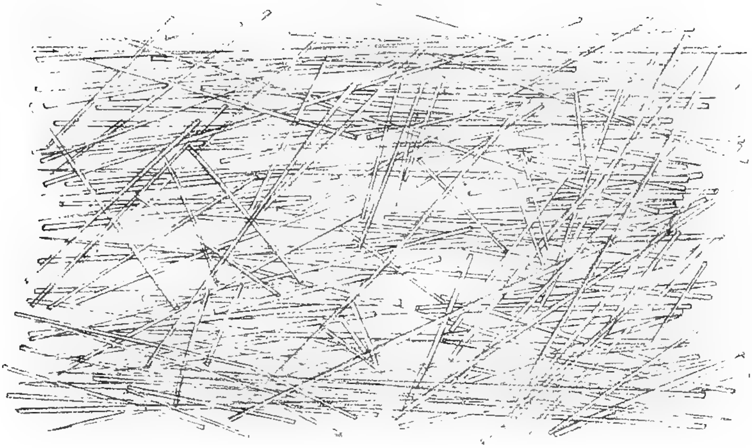


W Lens Aldous del et lith

W West imp

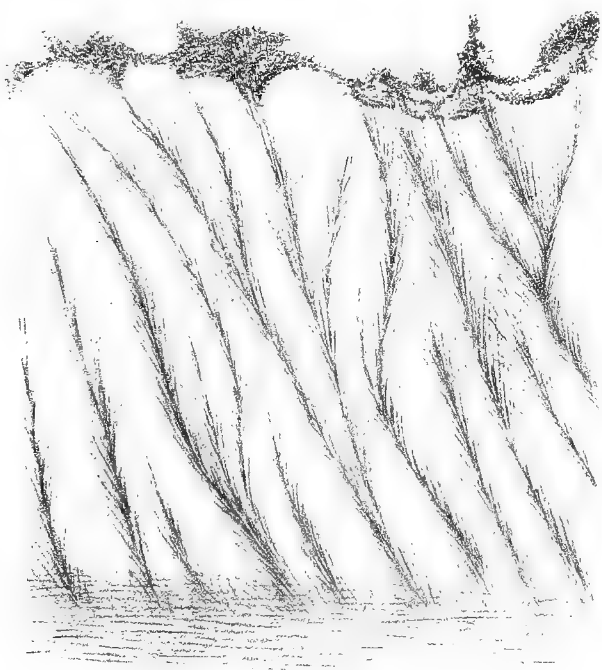
366 — 368

366



368

367

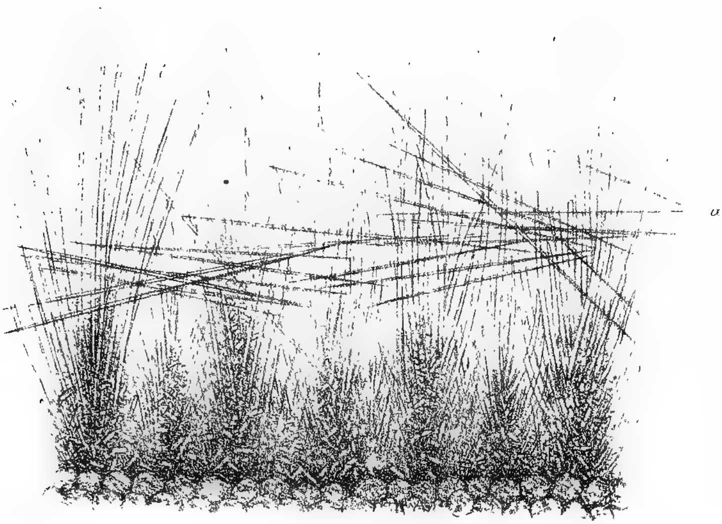


W Lens Aldous del et lith

W West imp

369 — 370

369



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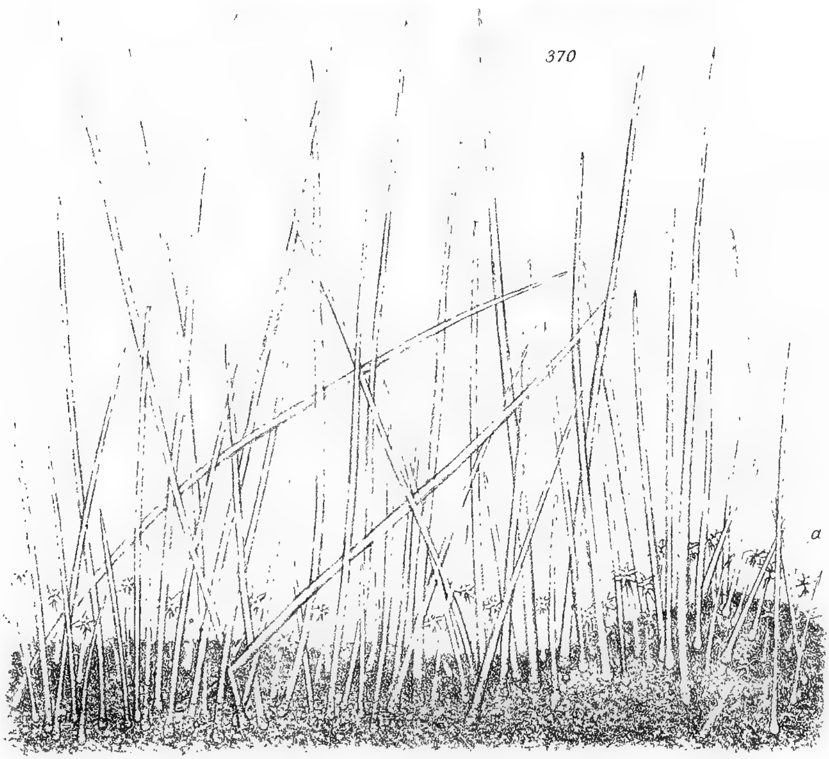


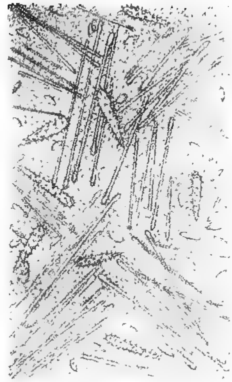
W Lens Aldous del et lith

W West imp

371 — 375.

372

371



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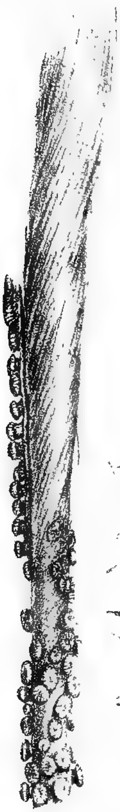

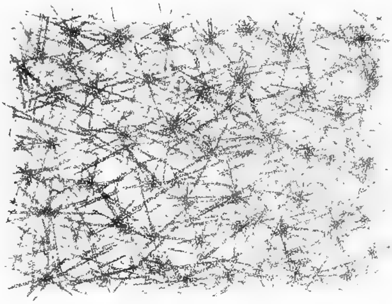

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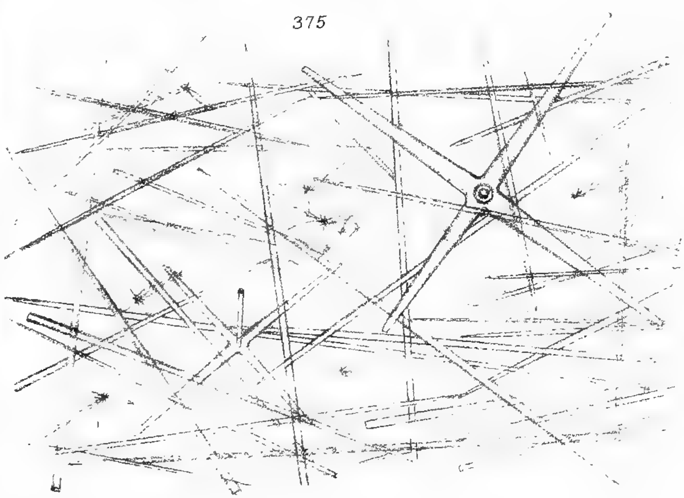
375

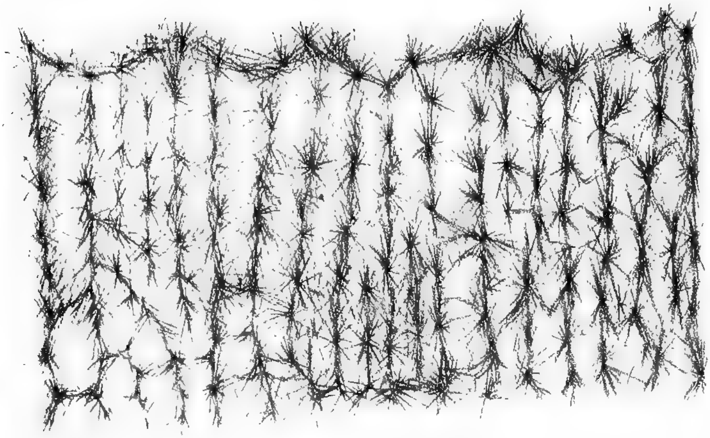


W Lens Aldous del. et lith.

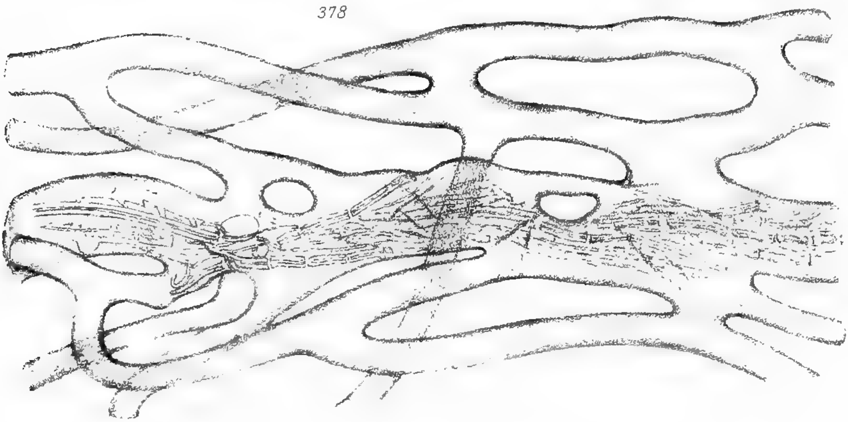
W West imp.

376 — 378

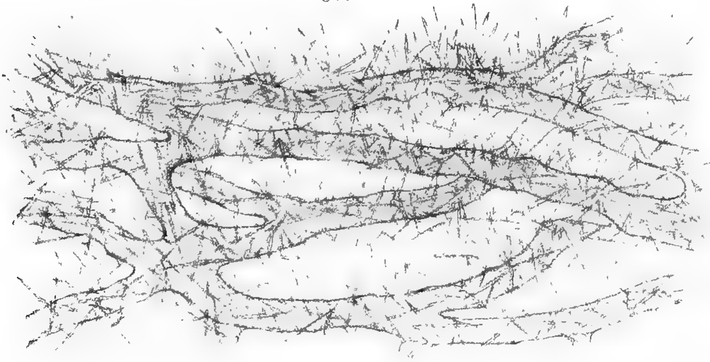
376



378



377



W Lens Aldous del et lith

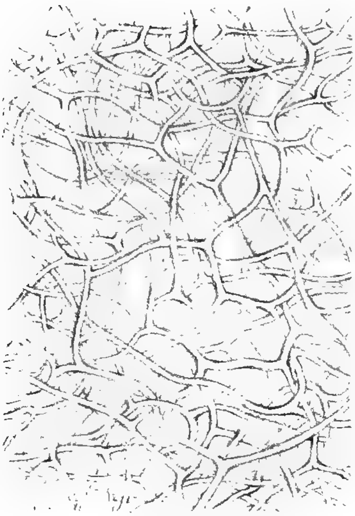
W West imp

379 — 381

152

151

379



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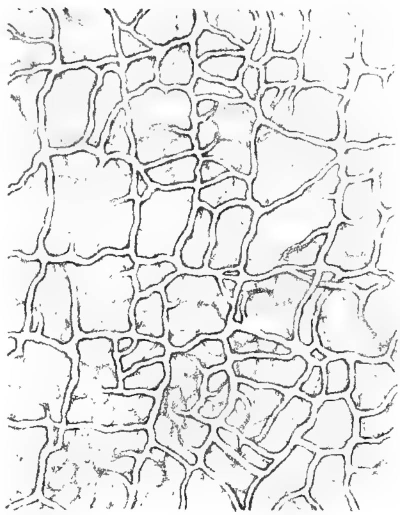

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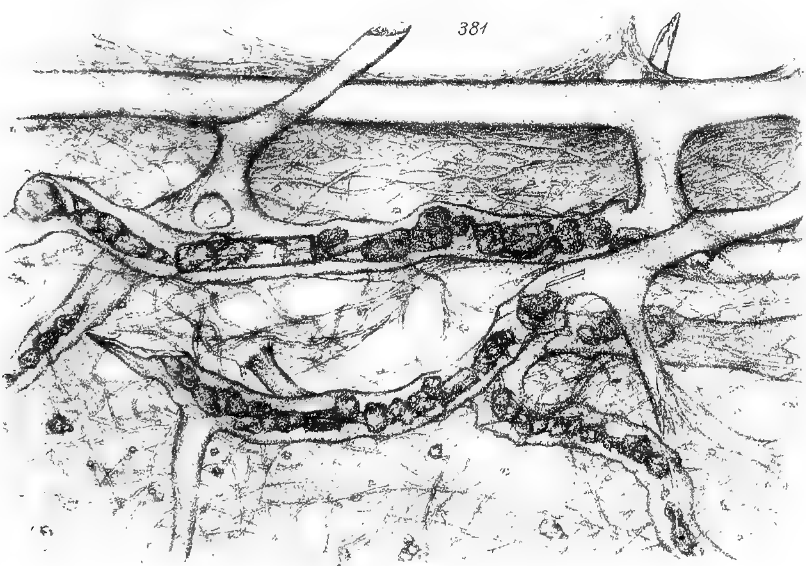

W Lens Aldous del et lith

W West imp